Section S8F - Stormwater Treatment Best Management Practice Evaluation

(1) CatchBasin StormFilter BMPs

Quality Management System Planning Document

Quality Assurance Project Plan

NPDES Phase I Municipal Stormwater Permit

Permit No.: WAR04-4503

Revision: R1D0(FINAL)

Effective date: 02/12/2009

Seattle Public Utilities
Seattle , Washington

This document is part of the Science Information Quality System providing in one place a clear, concise, and complete plan for environmental data management and its quality objectives, and for identifying key project personnel.

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1. TITLE AND APPROVAL SHEET

Quality Assurance Project Plan

NPDES Phase I Municipal Stormwater Permit

Internal Review and Approval

Ingrid Wertz	2/11/09
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Business Area Representative, NPDES Permit Coordinator (Kevin Buckley)	Approved On:
Douglas J. Hutchinson	2/11/09
Principle Investigator (Doug Hutchinson)	Approved On:
Amy Minichillo	2/11/09
QA Coordinator (Amy Minichillo)	Approved On:

I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for willful violations.

Nancy Ahern

Date: 2/11/09

Nancy Ahern, Deputy Director
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Acronyms

BMP	Best Management Practice
CAR	Corrective Action Report
COC	Chain of Custody
CWA	Clean Water Act
DMP	Data Management Plan
DMRG	Data Management Reference Guide
DQI	Data Quality Indicator
DQO	Data Quality Objective
DOC	Demonstration of Capability
EPA	Environmental Protection Agency
GIS	Geographic Information System
MDL	Method Detection Limit
NCR	Nonconformance Report
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PO	Project Officer
QA/QC	Quality Assurance/Quality Control
QAC	Quality Assurance Coordinator
QAM	Quality Assurance Manual
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
QMP	Quality Management Plan
RPD	Relative Percent Difference
SIC	Science Information Catalog
SLOC	Station Location Form
SOP	Standard Operating Procedure
WQI	Water Quality Indicator

2. TABLE OF CONTENTS

List of Diagrams

List of Tables

List of Figures

Quality Assurance Project Plan

NPDES Phase I Municipal Stormwater Permit

This Quality Assurance Project Plan (Plan), prepared by Seattle Public Utilities (SPU) with assistance from Herrera Environmental Consultants, Inc. (Herrera) for the City of Seattle (City), describes Part 1 of 2 of the *stormwater treatment best management practices (BMPs) monitoring study* required under Section S8F of the 2007 National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Stormwater Permit, permit number WAR04-4503. The scope of this Plan is CatchBasin StormFilter devices, proprietary BMPs designed to replace a standard catch basin and treat low flow volumes.

The permit, issued by the Washington Department of Ecology (Ecology) on January 17, 2007 with an effective date of February 16, 2007, under the NPDES and State Waste Discharge General Permit for discharges from Large and Medium Municipal Separate Storm Sewer Systems (Ecology 2007b), requires three types of monitoring under section S8:

> **Stormwater characterization** – field monitoring which is intended to characterize stormwater runoff quantity and quality to allow analysis of loadings and changes in conditions over time and generalization across the Permittees' jurisdiction.
>
> **Program effectiveness** - monitoring which is intended to improve stormwater management efforts by evaluating at least two stormwater management practices that significantly affect the success of or confidence in stormwater controls.
>
> **BMP Effectiveness** - full scale field monitoring to evaluate the effectiveness and operation and maintenance requirements of stormwater treatment and hydrologic management BMPs applied in their jurisdiction.

This Plan is the one of three that will be submitted to the Ecology to meet the permit requirements of Section S8 and covers the *BMP effectiveness monitoring* component of section S8F. The City submitted a "*Monitoring Approach Proposal*" to Ecology on October 7, 2007 and received conceptual approval from Ecology, pending final design details, on December 12, 2007 to monitoring the following treatment BMP types under S8F:

- Catch Basin StormFilter devices, the subject of this QAPP, and
- Biofiltration swales (modified and standard), which we now intend to replace with bioretention swales, the subject of the fourth QAPP to be submitted under this permit.

A draft version of this Plan was submitted to Ecology on September 9, 2008. Ecology reviewed the Plan and submitted comments to the draft letter in a letter data September 26, 2008. This final version of the Plan addresses Ecology's comments and updates project information.

The primary goal of this Plan is to define procedures that assure the quality and integrity of the collected samples, the representativeness of the results, the precision and accuracy of the analyses, the completeness of the data, and ultimately delivers defensible products and decisions for BMP treatment effectiveness monitoring described in Section S8F.

This document was developed with guidance from the Department of Ecology, Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004). A cross-walk with the Environmental Protection Agency Quality Assurance Project Plan (QAPP) format is included in Table T-19.

This Plan is organized and presented using the following elements:

I. Goals and objectives of the study,

II. Type, quality, and quantity of data needed to meet the objectives,

III. Sampling and measurement procedures needed to acquire those data,

IV. Study implementation Quality Assurance (QA)/Quality Control (QC) procedures to ensure the QAPP is implemented as prescribed, and

V. Assessment procedures to determine if the data conform to the specified criteria will satisfy the study objectives and the analysis and format for presentation of the results.

Large tables that will be used often during the study life have been located in a Tables section. These tables are noted with a "T" prefix.

A series of Standard Operating Procedures (SOPs) will be developed to provide guidance to users of this Plan. Table T-20 presents the proposed list of SOPs to be developed by the NPDES Phase I Permittees Collaboration Team. If the Collaboration Team SOP development schedule meets the needs of this study, these SOPs will be adopted. Otherwise, SOPs will be developed independently of the Collaboration Team.

Element I. Goals and Objectives of the Study

This element covers basic project management, including study history and objectives, roles and responsibilities of participants, and other factors to ensure that the study has a defined goal and clear outcomes understood by all the participants. This element includes the following sections:

Section 3 – Background,

Section 4 – Project Description, and

Section 5 – Organization and Schedule.

3. BACKGROUND

In July 1995, Ecology issued three NPDES wastewater discharge general permits to regulate municipal stormwater discharges. These permits required development and implementation of stormwater management programs to reduce the discharge of pollutants to the maximum extent practicable. The permits expired on July 5, 2000. The Washington Department of Ecology (Ecology) administratively extended permit coverage until they issued the revised permit in January 2007.

Ecology combined the three current general permits for the Island/Snohomish, Cedar/Green, and South Puget Sound Water Quality Management Areas (WQMA) into a single statewide general permit. The general permit applies to all entities required to have permit coverage under current (Phase I) U.S. Environmental Protection Agency (EPA) stormwater regulations. This includes cities and unincorporated portions of counties whose populations exceed 100,000. The 1995 Phase I permittees include:

- King County
- Pierce County
- Snohomish County
- Clark County
- City of Seattle
- City of Tacoma

Phase I Secondary Permittees include:

- Port of Seattle
- Port of Tacoma

Ecology intends for the combination of intensive monitoring from all Phase 1 Permittees throughout the state to provide them with a sufficient data set from which to draw conclusions about the effectiveness of treatment BMPs on a region-wide basis.

3.1. The Problem

Ecology (2006) has defined the problem to be addressed with the Best Management Practice (BMP) effectiveness monitoring as:

> "*Without the feedback loop, we haven't a good basis for altering design criteria in order to improve their performance.*

" We are overdue to perform studies to firm up our knowledge of the capabilities and limitations of the "best management practices" that we have been using to reduce the pollutant impacts of our developments."

3.1.1. Driver

Three basic control strategies exist for stormwater. First, prevent pollutants from coming into contact with stormwater by using source control best management practices (BMPs); second, apply treatment BMPs prior to discharge to surface or ground waters to reduce pollutants in the discharge; and third, control the flow rate of stormwater through flow control BMPs.

The focus of this study is evaluation of treatment BMPs. Treatment BMPs include ponds, swales, filtration, and infiltration devices that are designed to capture runoff and treat it using physical, biological, and/or chemical processes. The effectiveness and feasibility of treatment BMPs is variable, subject to some debate, and much remains to be learned (Ecology 2006).

The permit requires that each Phase I permittee select two treatment types, that are standard technologies in their manuals, for detailed performance monitoring. One of the two selected treatment types the City of Seattle has proposed monitoring is a proprietary treatment BMP, the Catch Basin StormFilter™ (CBSF).

The CBSF is becoming a frequently installed BMP to treat roadway runoff by the Seattle Department of Transportation (SDOT). We are interested in monitoring the effectiveness of this BMP because the cartridge technology has received a basic treatment General Use Level Designation (GULD) by Ecology via testing within a vault, not a Catch Basin device.

3.1.2. Decision-making

The results of this study are not intended for use in making specific decisions, but rather to provide a feedback loop to Ecology to improve their knowledge and understanding of the performance of treatment BMPs.

3.2. Study Area

Seattle was founded in 1865 and grew rapidly in the following decades forcing the City to develop drainage and wastewater infrastructure to protect the citizens and water supplies. The first systems in Seattle were engineered to combine wastewater and stormwater. As the City grew so did the drainage infrastructure which today includes combined, partially separated, and fully separated systems. Seattle Public Utilities operates and maintains the drainage system within the City of Seattle and adjacent areas, which includes approximately 1,850 miles of combined, partially separated, and separated conveyance structures (Ecology 2005).

As noted above, each permittee is required to select two treatment types that are standard technologies in their manuals for detailed performance monitoring. The City of Seattle has selected the following BMP as one of the two required treatment types for evaluation monitoring (Figure 1):

- Catch Basin StormFilters™ along California Avenue Southwest.

This site was selected based on a review of constructed BMPs within the City and the intent to meet the following criteria (Table 1):

- Listed in section S8F2,
- Meets design criteria of current Stormwater Management Manual for Western Washington (SMMWW),
- Technically feasible to monitor (access, drainage area, inlet concentration, other),
- Constructed and operable by 2009, and
- There are limited studies of the BMP within our region.

The selected BMP type provides basic treatment. The Catch Basin StormFilter ™, a proprietary treatment device, is not included on the BMPs listed in section S8F2 but the City received approval on December 12, 2007 from Ecology to move forward with evaluating this technology.

Table 1. BMP effectiveness monitoring projects.

BMP Type	BMP Project	On S8F2 List	Meets Design Criteria [1]	2 of Each	Feed-back Need
Catch Basin StormFilter ™	California Ave SW		✓	✓	✓

The Catch Basin StormFilter is a passive, flow-through stormwater filtration system. It is engineered to replace the standard catch basin, and consists of a concrete or steel vault that houses rechargeable cartridges filled with a variety of filtration media.

The Catch Basin StormFilters are installed at monitoring sites located along California Avenue SW in West Seattle, Washington (Figure 3). One of these units is located on the southeast corner of California Avenue SW and SW Spokane Street. The other unit is located on the southeast corner of California Avenue SW and SW Manning Street.

These units, which are model CBSF4, are 4-cartridge steel units designed to treat 0.065 cubic feet per second (Table 2). The CBSF is installed flush with the finished grade and is applicable for small drainage areas from roadways and parking lots, and retrofit applications.

Table 2. Construction specifications.

StormFilter Model	CBSF4
Number of Cartridges	4
Cartridge Height	18 inches
Outside Dimensions	10'8" x 2'5"
Approximate Weight (lbs)	1550
Material	Steel
Media	ZPG [2]
Total drop, rim to outlet (feet)	2.3
Conveyance flow – 25-year return period (cfs)	0.96

3.3. Parameters of Concern

Impacts from stormwater are highly site-specific and vary geographically due to differences in local land use conditions, hydrologic conditions, and the type of receiving water.

[1] See Ecology (2005) for criteria.
[2] The media was converted from perlite to ZPG in December 2008.

There are many pollution sources that may contaminate stormwater, including land use activities, operation and maintenance activities, illicit discharges and spills, atmospheric deposition, and vehicular traffic conditions. Many of these sources are not under the direct control of the municipalities that own or operate the storm sewers. Table 3 lists common stormwater pollutants with related potential sources. See Ecology (2006) for additional discussion on the impacts of stormwater pollutants.

Table 3. Common stormwater pollutants and their sources (Ecology 2006, modified).

Pollutant	Potential Sources
Arsenic	Atmospheric deposition (ASARCO Smelter, fossil fuel combustion)
Cadmium	Tire wear, metal plating, batteries
Chromium	Metal Plating, rocker arms, crank shafts, brake linings, yellow lane strip paint
Copper	Vehicles (brake pads, thrust bearings, bushings), copper pesticides, atmospheric deposition from fuel combustion and industrial processes
Lead	Motor Oil, transmission bearings, gasoline
Zinc	Vehicles (motor oil, tire wear), galvanized materials (roofing – flashing, dlown spouts, uncoated galvanized roofs, pipes, fencing)
Bacterial/Viral Agents	Domestic animals, septic systems, animal & manure transport
Nutrients	Sediments, fertilizers, domestic animals, septic systems, vegetative matter
Oil & Grease	Motor vehicles, illegal disposal of used oil
Organic Toxins	Pesticides, combustion products, petroleum products, paints & preservatives, plasticizers, solvents
Oxygen Demanding Organics	Vegetative matter, petroleum products
Sediments	Construction sites, stream channel erosion, poorly vegetated lands, slope failure, vehicular deposition
Temperature	Pavement runoff, loss of shading along streams

The water analytes identified as parameters of concern by Ecology are those that will provide information regarding the effectiveness of basic, enhanced, and phosphorus treatment BMPs (Table 4).

Table 4. Required parameters to be measured in water.

Analyte Group	Parameter
Conventional	Hardness
	pH
	Particle Size Distribution (PSD)
	Total Suspended Solids (TSS)
Metals (dissolved & total)	Copper
	Zinc
Nutrients	Orthophosphate
	Total phosphorus

The sediment analytes identified as parameters of concern by Ecology are those that will provide information regarding the effectiveness of basic, enhanced, phosphorus, or oil control treatment BMPs (Table 5).

Table 5. Parameters to be measured in sediment.

Analyte Group	Parameter
Conventional	Grain size
	Bulk density [3]
	Total solids
	Total Volatile Solids
Metals, total recoverable	Cadmium
	Copper
	Lead
	Zinc
Nutrients	Total phosphorus
Total Petroleum Hydrocarbons (TPH)	Diesel Range Organics (DRO)

4. PROJECT DESCRIPTION

This section presents the goals and objectives of the study; describes the boundaries, target populations and practical constraints of the study; and specifies the information and data required to meet the study objectives.

4.1. Study Goals

The study goal is to comply with Section S8F of the permit. Ecology's goal is to provide a performance feedback loop so they can confirm which BMPs perform best for certain pollutants. The Fact Sheet (2006) states:

> "*though most of these treatment types have been recommended and in common use for many years, we have only incomplete information about their pollutant removal capabilities. We have some confidence that they are based on sound engineering concepts, but we do not know how well they perform in relation to one another. Without a feedback loop of performance, we cannot confirm which BMP's perform best for certain pollutants*."

4.2. Study Objectives

Flow and water quality monitoring will be performed within each BMP in order to meet the following objectives:

- Quantify the treatment performance of each BMP for reducing both pollutant concentrations and loads.
- Determine the effectiveness of each BMP at treating the applicable water quality design flow.
- Determine if the treatment performance of each BMP varies in relation to storm event characteristics and/or other operational considerations.

In addition to the flow and water quality monitoring described above, sediment monitoring will be performed within each BMP in order to meet the following objectives:

- Quantify sediment accumulation rates within each component of the BMP for determining maintenance requirements.
- Evaluate the grain size distribution of accumulated sediment within each component of the BMP for use in assessing overall system performance.

[3] This is not a required parameter and will be analyzed at the discretion of the Principle Investigator.

- Evaluate pollutant concentrations in accumulated sediment within each component of the BMP.

4.3. Information Requirements

The sampling design for stormwater monitoring under S8F contains two primary activities that will be conducted at each monitoring site:

- Stormwater Sampling
- Sediment Sampling

General information that will be collected during these activities is described below. In addition, paragraph S8F4 requires "Permittees … must collect information pertinent to fulfilling the 'National Stormwater BMP Data Base Requirements' in section 3.4.3. of that document." This information includes National Stormwater BMP Database requirements for:

- All BMPs (Table T-21),
- Structural BMPs(Table T-22), and
- Individual structural BMPs (Table T-23).

Influent and effluent monitoring stations will be established in connection with each of the BMPs (Figure 5 and Figure 6).

Stormwater sampling Automatic flow-weighted composite sampling methods will be used to collect stormwater samples from qualifying storm events (Section 7.2.3 Qualifying Sample Criteria). Stormwater samples collected during each storm event will be analyzed for a suite of parameters that are identified in the Phase I Municipal Stormwater Permit for evaluating basic, enhanced, and phosphorus treatment performance (Table 4).

Hydrologic monitoring will involve measurements of discharge, water level (for estimating discharge using a primary measuring device [e.g., weir]), as well as precipitation depth. Discharge data will be used to characterize the peak discharge rate, the runoff volume, and the flow duration at each station. Precipitation data will be used to characterize the storm event antecedent dry period, total rainfall distribution during the sampled events, inter-event dry period, and rainfall average and peak intensity during the sampled storm events.

Sediment sampling Sediment samples collected will be analyzed for a suite of parameters that are identified in the Phase I Municipal Stormwater Permit for evaluating basic treatment performance (Table 5).

4.4. Study Boundaries

This section describes spatial and temporal boundaries of the problem, the scale of decision-making when appropriate, the characteristics that define the population of interest, and any practical constraints on data collection.

4.4.1. Spatial Boundary

The spatial boundary defines the geographic area within which all decisions will apply and the physical area to be studied and from where the samples will be collected.

Ecology may apply any decisions resulting from this study within the Phase I permittees' jurisdictions.

The BMPs are located within west Seattle on California Avenue West (Figure 1). Table 6 summarizes the geographic information for the selected BMPs.

Table 6. CatchBasin StormFilter design specifications & sample stations.

	CBSF1	CBSF2
Cross-street location	SW Spokane St	SW Manning St
Rain gage	RG14	RG14
Catchment area (acres)	0.18	0.23
Land use	Arterial	Arterial
Bypassed flow (BP) and treated flow (FM) stations	CBSF1-BP and FM	CBSF2-BP and FM
Water quality influent (in) and effluent (out) stations	CBSF1-In and Out	CBSF2-In and Out
Sediment quality stations (1 in the influent sump, 2 and 3 in each cartridge chamber)	CBSF1-Sed-1, 2, and 3	CBSF2-Sed-1, 2, and 3

4.4.2. Temporal Boundaries

The temporal boundary defines the timeframe to which the decision applies and when data will be collected.

It is anticipated that sample collection and reporting activities will extend beyond the current permit cycle (February 2007 – February 2012) by approximately 6 months, to August 2012.

Each station will be equipped with automated equipment to facilitate continuous monitoring of flows over the 3 year duration of this study (February 2009 – February 2012) and the collection of influent and effluent flow-weighted composite samples during discrete storm events over this period. The collection of flow-weighted composite samples will occur for 8 to 12 storm events in each year of the study to achieve a goal of obtaining up to 30-paired influent and effluent samples at each BMP by the end of the study period.

4.4.3. Target Population

The characteristics that define the population of interest are basic treatment performance of Catch Basin StormFilters from the California Avenue Southwest project within the City of Seattle.

4.4.4. Practical Constraints

The three primary practical constraints to a successful study are discussed below and include:

1) Sampling design assumptions and requirements;

2) Construction and installation of equipment in time to meet the permit deadline to begin sampling; and

3) Typical logistical challenges associated with the difficult task of monitoring stormwater.

Sampling design– The CBSF treats sheet flow from the road surface, which may be difficult to sample.

Construction schedule – Each selected site has specific construction and equipment installation issues. Equipment installation may include the need to obtain permits, entering into agreements with contractors, close the street to replace pipe sections, install new maintenance holes, etc.

Logistical challenges - The unpredictable nature of storm events poses the greatest logistical challenge for this study. Only storms of particular depths and intensities will result in qualifying storm events and successful sample collection. However, the location, timing, duration, magnitude, and intensity of storm events cannot be forecast with certainty.

Since long-term forecasts have greater uncertainty, mobilization of field staff and equipment setup for a potential storm sampling event cannot happen more than two days ahead of a forecasted storm.

Although Standard Operating Procedures (SOPs) will be followed, it is inevitable that during this long duration and intense monitoring study equipment malfunction and human error will result in unsuccessful sample collection of qualifying storm events.

Although sites are selected to minimize safety concerns, traffic control may be necessary to access the monitoring stations safely. This is a special concern with the California Avenue SW CBSF sampling. Access may be necessary during high traffic periods, at night, and/ or during severe weather. These access conditions pose additional logistical challenges for sample collection.

5. ORGANIZATION AND SCHEDULE

This section describes the roles & responsibilities of the study team, the study timeline, and schedule.

5.1. Roles & Responsibilities

The team consists of representatives from key groups with a role in data collection or use, and often those with a critical interest or stake in the problem. This section includes the names, duties, and responsibilities of all key team participants. This includes internal and external team members. The organizational structure is designed to provide project control and proper quality assurance/quality control (QA/QC) for the field investigation.

The roles of key individuals involved in the study are provided in Table 7. A detailed description of the lines of authority and reporting between these individuals and organizations is presented in Diagram 1and the responsibility associated with each role is outlined in Table 8.

Table 7. Study Team

Role	Name	Organization	Telephone No.
NPDES Permit Coordinator (Business Area Representative)	Kevin Buckley	SPU	206.733.9195
Study Manager	John Lenth	Herrera	206.441.9080
NPDES Monitoring Lead (Principle Investigator)	Doug Hutchinson	SPU	206.233.7899
QA Coordinator	Amy Minichillo	SPU	206.684.0974
Field Supervisor	Dylan Ahern	Herrera	206.441.9080
Data Steward	Ann McNally	SPU	206.386.9786
Contract Laboratory PM	Mark Harris	Analytical Resouces Inc.	206.695.6200

In general, the Principle Investigator (PI), reporting to the Business Area Representative (NPDES Permit Coordinator), is assigned to manage the stormwater BMP effectiveness monitoring program. In this role, he/she provides technical expertise; coordinates sampling activities with the laboratory and the study manager, who coordinates the field team; and reports the status and results of the study to the Business Area Representative.

The Business Area Representative provides direction to the PI and communicates with the Ecology Regional Representative.

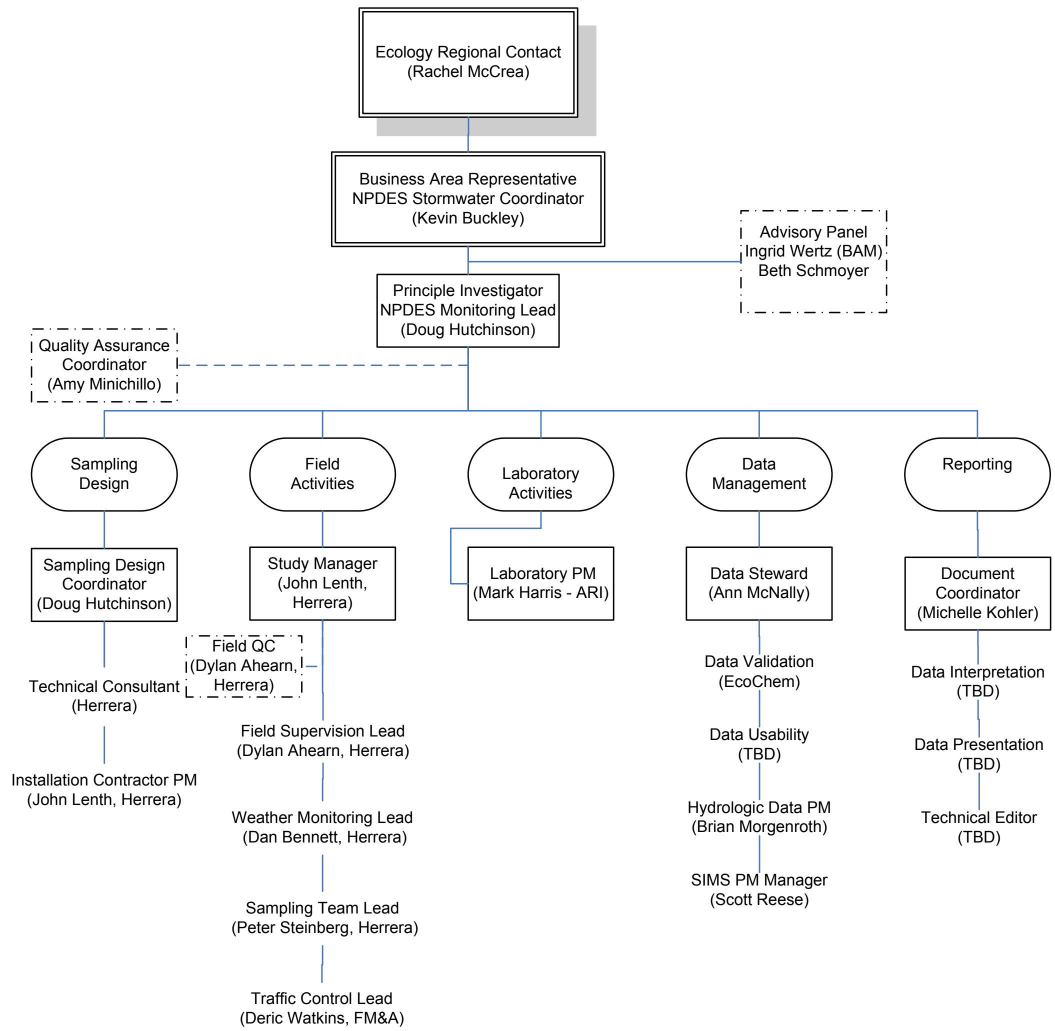

Diagram 1. Organization chart showing lines of communication.

A description of the detailed responsibility of each role is outline below in Table 8.

Table 8. Roles & responsibilities

Roles & responsibilities
Advisory Panel The Advisory Panel attends intermittent meetings for review process of the overall program in order to confirm or refute whether the study objectives are being met. The group may make suggestions for changing specific procedure or overall organization in the event that the study design fails to meet the stated goals.
Business Area Manager (BAM) Responsible for overall monitoring program including fiscal resources and personnel.

Roles & responsibilities
Approves QAPP.
Business Area Representative (BAR) Carries out needs and requirements set by the Business Area Manager. Coordinates with Ecology representative. Provides study/program direction. Ensures that there is sufficient managerial, technical and support staff with the authority and resources (equipment, etc.) to perform their stated duties. Establish procedures to ensure that all personnel are free from any undue internal or external commercial, financial, and other pressures or influences that may adversely affect the performance and quality of their work.
Principle Investigator (PI) Responsible for the development, approval, implementation, and maintenance of the QAPP. Acts as a liaison between the analytical laboratory, the study manager, the field team leader, the QAC and the organization. Responsible for: maintaining records of QAPP distribution, including appendices and amendments; maintaining written records of sub-tier commitment to requirements specified in this QAPP; identifying, receiving, and maintaining study quality assurance records; coordinating with the QAC to resolve QA- related issues. Notifies Business Area Representative of particular circumstances which may adversely affect the quality of data derived from the collection and analysis of samples. Ensure that the staff has the necessary education, experience, and/or training to perform their stated duties. Enforces corrective action.
Quality Assurance Coordinator (QAC) Reports to the Principle Investigator indirectly and is independent of the field, laboratory, data, and reporting staff. Major responsibilities include monitoring QC activities to determine conformance, distributing quality related information, training personnel on QC requirements and procedures, reviewing QA/QC plans for completeness and noting inconsistencies, and signing-off on the QA plan and reports.
Study Manager (SM) Responsible for ensuring tasks and other requirements in the contract for field implementation are executed on time and are of acceptable quality. Monitors and assesses the quality of work. Coordinates attendance at conference calls, training, meetings, and related study activities. Responsible for verifying the QAPP is followed and the study is producing data of known and acceptable quality. Ensures adequate training and supervision of all monitoring and data collection activities. Complies with corrective action requirements. Supervises the assigned study personnel (scientists, technicians, and support staff) in providing for their efficient utilization by directing their efforts either directly or indirectly on studies. In general, other specific responsibilities include: coordinate study assignments in establishing priorities and scheduling, ensure the completion of high-quality studies within established budgets and time schedules, provide guidance and technical advice to those assigned to studies by evaluating performance, implement corrective actions and provide professional development to staff, and prepare and/or review preparation of study deliverables, interact with clients, and technical reviewers to assure technical quality requirements are met in accordance with contract specifications.
Sampling Design Coordinator Responsible for completion of the sampling design by coordinating resources from the consultant, statistician, senior contributing personnel, and the needs of the user.
Document Coordinator Responsible for on-schedule completion of assigned writing, editing, and data interpretation work. Directs all reporting activities, including in-house and outside review, editing, printing, copying, and distributing or journal submission.
Field Supervisor Responsible for: supervising all aspects of the sampling and measurement in the field; the acquisition of samples and field data measurements in a timely manner that meet the quality objectives; field scheduling, staffing, and ensuring that staff are appropriately trained.
Data Steward Responsible for the acquisition, verification, and transfer of data to the SPU database. Oversees data management for the study. Ensures data are submitted according to work plan specifications. Responsible for validation and verification of data collected. Provides the point of contact to resolve issues related to the data.
Laboratory Manager Responsible for supervision of laboratory personnel involved in generating analytical data for this study. Responsible for ensuring that laboratory personnel involved in generating analytical data have adequate training and a thorough knowledge of the QAPP and all SOPs specific to the analyses or task performed and/or supervised. Responsible for oversight of all operations, ensuring that all QA/QC requirements are met, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates monitoring systems audits.
Laboratory QAO Monitors the implementation of the Quality Assurance Manual (QAM) and the QAPP within the laboratory to ensure complete compliance with QA objectives as defined by the contract and in the QAPP. Conducts internal audits to identify potential problems and ensure compliance with written SOPs. Responsible for supervising and verifying all aspects of the QA/QC in the laboratory. Performs validation and verification of data before the report is sent to the contractor. ensures that all QA reviews are conducted in a timely manner from real-time review at the bench during analysis to final pass-off of data to the QA officer.

5.2. Special Training Needs/Certification

This section identifies and describes any specialized training or certifications needed by personnel in order to complete the study or task successfully.

Field personnel will receive training in proper sampling and field analysis for each Standard Operating Procedure they will be using. They will demonstrate to the Field Supervisor (in the field), their ability to properly operate the automatic samplers and retrieve the samples. The Field Supervisor will sign off each field staff in their field logbooks.

Field staff whom collect positional data shall undergo a training program to ensure that he or she has the knowledge and skills required to collect data in accordance with SOPs for GIS.

In addition to technical training, field personnel will receive training that addresses stormwater monitoring activities that have the potential to adversely affect their health and safety. Stormwater monitoring field crews often work in wet, cold, and poor visibility conditions. Sampling sites may be located in high traffic areas or remote, poorly lit areas that need to be accessed on a 24-hour basis. Monitoring personnel and workers installing or maintaining equipment may be exposed to traffic hazards, confined spaces, biological hazards (e.g., medical waste and fecal matter), vectors (e.g., snakes and rats), fall hazards, hazardous materials, fast moving stormwater, and slippery conditions. A health and safety plan will be developed for each site. The health and safety plan will include detailed training and procedures to address confined spaces, vehicle traffic, open manholes and manhole lids, open water hazards, biological hazards, and chemical hazards.

The selected laboratory will be accredited or registered under the provisions of Accreditation of Environmental Laboratories, Chapter 173-50 WAC.

5.3. Timeline/study schedule

This section specifies the relevant deadlines for the study. The critical milestones to be met to meet the study implementation deadline of February 16, 2009 are below.

Key dates include:

February 16, 2008	Summary description of the monitoring program and Quality Assurance Project Plan (QAPP) submitted to Ecology.
May 16, 2008	Ecology completes review of the QAPP and responds with comments to the City.
September 11, 2008	SPU submits revised QAPP for Ecology review and approval
September 26, 2008	Ecology provides comments on the QAPP
February 16, 2009	Revised final QAPP submitted to Ecology.
February 16, 2009	Full implementation of the monitoring program begins.
March 31, 2010	First annual report due covering the period from February 16, 2009 through September 30, 2009
March 31, 2011	Second annual report due covering first complete water year, from October 1, 2009 through September 30, 2010.

Table 9 summarizes the tasks needed to be accomplished and their schedule to secure analytical laboratories by February 16, 2009. The Statement of Work will address issues such as acceptance of a large composite sample, sample delivery acceptance hours, turn around times, method reporting limits, etc.

Table 9. Target analytical laboratory contracting schedule.

Activity	Expected Date of Completion
Finalize Statement of Work (SOW) boiler plate language	September 30, 2008
Finalize Electronic Data Deliverable format and contents	September 30, 2008
Prepare a Statement of Work (SOW)	October 15, 2008
Prepare a Request for Quote	October 30, 2008
Evaluate Quotes	November 21, 2008
Select a laboratory	November 30, 2008
Finalize contract	December 15, 2008
Notify Ecology of selected laboratory	December 31, 2008

Table 10 outlines the target equipment installation and testing schedule needed to meet the monitoring initiation date of February 16, 2009.

Table 10. Target equipment installation and testing schedule.

Activity	CBSF (California Ave SW)
Finalize Equipment List and Order Equipment	September/October 2008
Install Equipment	October 2008
Initiate Flow Monitoring	November 2008
Evaluate Flow Data and Pacing Rates	December 2008
Water sampling equipment testing	January 2008

5.3.1. Study Deliverables

This section describes the study deliverables. Section 14.2 provides additional details describing the procedure and method for developing the deliverables. Refer to Section 11 for documentation and records supporting development of the deliverables and Section 15 for a discussion of the content. Table 11 presents the study timeline and schedule as well as study deliverables.

The study results will be presented in an annual report. Each annual report will include all monitoring data collected during the preceding water year (October 1 – September 30). The first annual monitoring report submitted will include data from a partial water year, February 16, 2009 through September 30, 2009. Each report shall also integrate data from earlier years into the analysis of results, as appropriate. Reports shall be submitted in both paper and electronic form and shall include:

1) A summary including the BMP type location, land use, drainage area size, and hydrology for each site.
2) The status of implementing the monitoring program,
3) A comprehensive data and QA/QC report for each part of the monitoring program, with an explanation and discussion of the results of each monitoring study, and
4) Performance data.

Table 11 provides a schedule of activity and deliverables for the study.

Table 11. Study deliverable schedule.

Performance Monitoring Period	Anticipated No. of Events	Anticipated Date of Initiation	Anticipated Date of Annual Completion	Deliverable and Due Date
Partial Water Year One (2009)	2-6	02/16/2009	09/30/2009	Stormwater Monitoring Report [4] March 31, 2010
Water Year Two (2010)	8-12	10/01/2009	09/30/2010	Stormwater Monitoring Report March 31, 2011
Water Year Three (2011)	8-12	10/01/2010	09/30/2011	Stormwater Monitoring Report March 31, 2012
Partial Water Year Four (2012) [5]	4-8	10/01/2011	02/15/2012	Study Monitoring Report August 15, 2012

5.3.2. Study success factors

It is anticipated that five additional plans may be developed to support the sampling efforts and increase the chances for a successful outcome (Table 12).

Table 12. Anticipated additional plans needed to support sampling activities.

Plan	Purpose	Responsible for prepared & Implementation
Communication Plan	Provide anticipated communication between the Principle Investigator, analytical laboratories, Study Manager, and field teams. Includes process to keep the laboratory informed of the schedule for sample delivery. For example, the plan will include the following: the analytical laboratory will be contacted prior to the forecasted storm event to ensure adequate staff will be available for processing incoming samples.	Study Manager
Construction Plan	Develop construction schedule, identify any permits needed (i.e. Seattle Department of Transportation (SDOT), Seattle City Light, etc.), develop power and communication needs list, etc.	Study Manager
Implementation Plan	Property access, storm event response, equipment availability, back up options as needed, etc.	Study Manager
Traffic Control Plan	SDOT permits, required training, flagging needs, etc.	Study Manager
Health & Safety Plan	Personnel hazards including confined space entry.	Study Manager

[4] Submitted with Annual Report
[5] May extend past 2012 if more samples are needed.

Element II. Type, Quality, and Quantity of Data Needed

This element describes the type, quality, and quantity of data needed to meet the study objectives and includes:

> Section 6 - Quality Objectives, which describe the type and quality of data needed to meet the study goals and objectives, and
>
> Section 7 - Sampling Process Design, which determines the quantity of data needed.

6. QUALITY OBJECTIVES

This section describes the study data quality and measurement quality objectives, which describe the type and quality of data needed to meet the study goals and objectives.

Data Quality Objectives (DQOs) are qualitative and quantitative statements developed using the data quality objectives process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors. These will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Once established, DQOs become the basis for the measurement quality objectives (MQOs) that are used specifically to address analytical and hydrologic monitoring equipment performance.

Measurement Quality Objectives (MQOs) are “acceptance criteria” for the quality attributes measured by the study data quality indicators (DQIs). During study planning, measurement quality objectives are established as quantitative measures of performance against selected data quality indicators, such as precision, bias, representativeness, completeness, comparability, and sensitivity. By extrapolation, data that meets defined MQOs are considered acceptable for use in study decision making.

6.1. Data Quality Objectives

The statistical goal for treatment BMP effectiveness monitoring is to determine mean effluent concentrations and mean percent removals with 90 to 95 percent confidence and 75 to 80 percent power (S8F4). Based on expected coefficients of variation for stormwater pollutant parameters, it is likely that these statistical goals can be reached with between 12 to 30 sample pairs. However, in the event of a large coefficient of variation, a maximum of 30 sample pairs will suffice, and the confidence and power will be identified.

6.2. Measurement Quality Objectives

Measurement quality objectives (MQOs) specify how good the data must be in order to meet the objectives of the study. MQOs are the performance or acceptance thresholds or goals for the study’s data, based primarily on the data quality indicators (DQIs). Another name for MQOs is measurement performance criteria (MPC). For existing data, these correspond to acceptance criteria. MQOs are used to select procedures for sampling, analysis, and quality control (QC).

Of the six principal data quality indicators: precision, bias, and sensitivity are quantitative measures; representativeness and comparability are qualitative; completeness is a combination of both qualitative and quantitative measures; and accuracy is a combination of precision and bias. Please refer to the Glossary for definitions of each DQI. Table T-24 summarizes the MQO for each DQI and a short discussion follows.

6.2.1. Precision, Bias, Accuracy, and Sensitivity

Precision, bias, accuracy, and sensitivity MQOs for the study are specified in Table T-25 through Table T-29 for hydrologic, water, and sediment parameters respectively as appropriate.

6.2.2. Representativeness

The representativeness of the data is dependent on 1) the sampling locations, 2) the flow regime during sample collection 3) the number of years sampling is performed, and 4) the sampling procedures. Site selection and sampling of pertinent media (i.e., water) and use of only approved analytical methods will assure that the measurement data represents the population being studied at the site.

The representativeness of the water quality data to be collected through this study will be ensured by targeting representative storms for sampling based on the criteria (Table 14 and Table 15*)*: that were derived from the Phase I Municipal Stormwater Permit (Ecology 2007b) and recommended procedures from Ecology (2008) in *Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE).*

The representativeness of the sediment quality data to be collected through this study will be ensured by employing consistent and standard sampling procedures. In addition, the representativeness of these data will be ensured by selecting sampling locations that take into account the physical processes that influence location and rate of sediment accumulation within stormwater treatment BMPs.

The representativeness of the hydrologic data will be ensured by the proper selection and installation of all associated monitoring equipment. Rainfall patterns, stormwater conveyance features, and surrounding land uses were also considered in the identification of monitoring locations and sampling frequencies to ensure that representative data will be obtained for this study. Finally, monitoring will be conducted over a sufficient length of time (3 years) to ensure that data are collected during representative climatic conditions for the region.

6.2.3. Completeness, and Comparability

The completeness of the data will be maximized by using proven sampling techniques, packaging samples for transport to avoid breakage, and timely processing at the laboratory. The analytical requirements will be met to assure acceptable data. Where possible, excess sample will be archived until the laboratory results can be reviewed by the project manager. A completeness target of 90 percent has been set for this study.

Confidence in the comparability of data sets for this study is based on the commitment of study staff to use only approved sampling and analysis methods and QA/QC protocols in accordance with quality system requirements and as described in this QAPP and in SOPs. Comparability is also guaranteed by reporting data in standard units, by using accepted rules for rounding figures, and by reporting data in a standard format.

7. SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

This sampling process design was developed based on monitoring requirements identified in the Phase I Municipal Stormwater Permit (Ecology 2007b) and recommended procedures from Ecology (2008) in *Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE)*.

As described previously, the specific objectives of this monitoring study are as follows:

- Quantify the treatment performance of each BMP for reducing both pollutant concentrations and loads.
- Determine the effectiveness of each BMP at treating the applicable water quality design flow.
- Determine if the treatment performance of each BMP varies in relation to storm event characteristics and/or other operational considerations.

In addition to the flow and water quality monitoring described above, sediment monitoring will be performed within each BMP in order to meet the following objectives:

- Quantify sediment accumulation rates within each component of the BMP for determining maintenance requirements.
- Evaluate the grain size distribution of accumulated sediment of the BMP for use in assessing overall system performance.
- Evaluate pollutant concentrations in accumulated sediment of the BMP.

A short discussion of the BMP operation and design criteria, monitoring strategy, and the detailed flow and water quality monitoring equipment selection follows.

7.1. BMP Operation & Design Criteria

Model CBSF4 consists of a multi-chamber steel catch basin unit that can contain up to four StormFilter cartridges. The CBSF is installed flush with the finished roadway and is applicable for both new and retrofit applications. The standard CBSF4 model treats peak water quality design flows up to 0.07 cfs, coupled with an internal weir overflow capacity of 1.0 cfs (Contech 2006).

Each model CBSF4 Catch Basin StormFilter™ is designed with the following primary components: influent sump, scum baffle, two filter cartridge chambers containing two StormFilter™ cartridges each, internal bypass weir, and an effluent/bypass chamber (see Figure 4). Stormwater initially enters the influent sump where some treatment may occur via particle settling. It then passes under the scum baffle, leaving floatable pollutants behind in the influent sump. Next, the stormwater may be routed into one of two cartridge chambers for treatment via the StormFilters™ cartridges; alternatively, if the treatment capacity of the StormFilters™ cartridges has been exceeded or the storm flow exceeds the design flow, the stormwater can bypass the cartridge chambers entirely by spilling over the bypass weir. Treated effluent from the StormFilters™ cartridges and bypassed stormwater enter the effluent/bypass chamber and are subsequently discharged out of the system via an 8-inch outlet pipe.

The CBSF is sized using the Western Washington Hydrology Model Version 3 (WWHM3), an Ecology-approved continuous runoff model. The unit is sized assuming an online, or flow-through facility, based on the manufacturer's recommendation (page 80-81, Contech 2006) and the definition provided in the Stormwater Management Manual for Western Washington (Ecology 2005), Section 4.5 Hydraulic Structures, 4.5.1 Flow Splitter Designs:

> "*Many water quality (WQ) facilities can be designed as flow-through or on-line systems with flows above the WQ design flow or volume simply passing through the facility at a lower pollutant removal efficiency. However, it is sometimes desirable to restrict flows to WQ treatment facilities and bypass the remaining higher flows around them through offline facilities. This can be accomplished by splitting flows in excess of the WQ design flow upstream of the facility and diverting higher flows to a bypass pipe or channel*."

Because the CBSF is fitted with an internal bypass weir, all stormwater enters the unit and receives some treatment in the influent sump. Flows bypass the cartridge when they either exceed the design flow rate or the cartridge capacity has been exhausted.

The cartridges to be tested in this study will be zeolite-perlite-granular activated carbon (ZPG) cartridges. Each cartridge contains a total of approximately 2.6 cubic feet (CF) of media. The ZPG cartridge consists of an outer layer of perlite that is approximately 1.3 CF in volume and an inner layer, consisting of a mixture of 90% zeolite and 10% granular activated carbon, which is approximately 1.3 CF in volume. The ZPG cartridges to be tested are manufactured to meet the specifications described in Ecology's General Use Level Designation (GULD) for Basic Treatment issued January 2005 and updated December 2007.

Table 13 lists the design specifications for each CBSF proposed for monitoring: CBSF1, located near Southwest Spokane Street, and CBSF2, located near Southwest Manning Street. To meet the conditions of the General Use Level Designation (Ecology 2007a) and prepare the units for monitoring the following tasks will be accomplished:

- The units will be cleaned and cartridges removed,
- The media will be converted from perlite to zeolite-perlite-granular activated carbon (ZPG),
- The individual cartridge flow rate will be reduced from 15 gpm to 7.5 gpm by modifying the orifice-control disc placed at the base of the cartridge, and
- Each unit will be adapted so that only one of the two two-cartridge filtration chambers is in use during the study. This will be accomplished by installing plugs in both the 4-inch inlet orifice to the filtration chamber and the 2-inch outlet orifice from the filtration chamber in one of the chambers (
- Figure 4). This adaptation will allow monitoring at close to the water quality design flow rate (Table 13).

Table 13. CBSF design criteria to be evaluated.

	Design Specs for Model CBSF4	Design Specs for Model CBSF4 modified for 2 cartridges	Expected Range CBSF1[6]	Expected Range CBSF2
Cross-street			SW Spokane St	SW Manning St
Construction Drawing Reference			Sheet 22, SD6	Sheet 23, SD8

[6] Expected range estimated using Western Washington Hydrology Model Version 3 (WWHM3) with SeaTac precipitation record from 1948 through 1998 and a scale factor of 1. Road slopes ranging from flat (0 to 5 percent) to steep (greater than 15 percent).

	Design Specs for Model CBSF4	Design Specs for Model CBSF4 modified for 2 cartridges	Expected Range CBSF1[6]	Expected Range CBSF2
Catchment Area (acres)		--	0.18	0.23
Mass load removed (lbs/cartridge)[7]	36	22-36	22-36	22-36
Conveyance flow (cfs)[8]	0.96	1-1.033	0.07 to 0.08	0.09 to 0.10
Water quality design flow (online, cfs)	0.065[9]	0.033	0.031 to 0.039	0.037 to 0.041
Typical flowrate through cartridge (gpm)[10]	7.5		1.5 to 4.5	1.5 to 4.5

An inspection standard developed by the manufacturer has been adopted by SPU to determine a site specific maintenance schedule. The inspections are conducted on a regular schedule and the general condition of the device, such as the condition of the lids, site access, any obstructions to flow, and orientation of lid slots are noted. Measurements are made of the following to facilitate an optimum maintenance schedule.

Inspection and observation in the inlet bay and each cartridge bay for:

- Solids accumulation depth (inches above the floor).
- Static water level (inches above the floor).

Inspection and observation in each cartridge bay for:

- Solids accumulation depth (inches above the floor).
- Solids accumulation depth on top of each cartridge (inches above the cartridge).
- Static water level (inches above or below bottom of the cartridge).
- Bay wall scum line (inches above or below bottom of the cartridge).

Depending on the results of the inspection, a maintenance standard developed by the manufacturer and adopted by SPU may be triggered. Maintenance includes removing accumulated sediment from the sump and replacing spent cartridges with recharged cartridges.

7.2. Monitoring Strategy Overview

A discussion of the stormwater monitoring strategy developed to meet the requirements of Section S8F and the recommended procedures from Ecology (2008) in *Guidance for*

7 A value of 36 pounds per cartridge assumes that 60 percent of mass load is trapped in the cartridge media and 40 percent of mass load is collected on the vault floor (Contech 2006).

8 Internal bypass of 1 cfs (Contech 2006) plus a maximum of 7.5 gpm x 2 cartridges (0.033 cfs). Design drawings show a conveyance flow 0.96 cfs with a 25-year peak flow event. Expected range estimated using WWHM3.

9 Design capacity is based on 4-cartridge unit at 7.5 gpm per cartridge. Design drawings assume 15 gpm per cartridge for a design capacity of 0.13 cfs.

10 From Ecology (2007b): "Due to the characteristics of the hydrographs, generally the field results reflect flows below (ranging between 20 and 60 percent of) the tested facilities' design rate. During these sub-design flow rate periods, some of the cartridges operate at or near their individual full design flow rate (generally between 4 and 7.5 GPM for an 18" cartridge effective height) because their float valves have opened. Float valves remain closed on the remaining cartridges, which operate at their base "trickle" rate of 1 to 1.5 GPM." For a 7.5 gpm cartridge, this is equivalent to an expected range of 1.5 to 4.5 gpm (20 to 60 percent of 7.5 gpm per cartridge).

Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE) is presented below. The actual sampling procedures to be implemented in connection with this sampling process design are described in Section 8.

Monitoring of two Catch Basin StormFilters™ will occur at sites located along California Avenue SW in West Seattle, Washington (Figure 2, Figure 3). One of these units (hereafter referred to as CBSF1) is located on the southeast corner of California Avenue SW and SW Spokane Street. The other unit (hereafter referred to as CBSF2) is located on the southeast corner of California Avenue SW and SW Manning Street.

Figure 5 shows the location of the monitoring stations that will be established in CBSF1 and CBSF2. More detailed schematics for each individual station are also provided in Figure 6. Finally, the type, location, purpose, and sampling frequency for each of these stations are also summarized in Table T-30.

A total of four monitoring stations will be established in CBSF1 and CBSF2, respectively, to measure the quantity and quality of influent and effluent stormwater. Specifically, the following types of stations will be established in association with each unit:

- Influent water quality,
- Effluent water quality,
- Treated and bypassed flow, and
- Bypassed flow only.

Additional description of the monitoring strategy is discussed below and includes:

- Selection of parameters and analytical methods,
- Selection of sampling techniques and types, and
- Selection of sampling frequency and criteria to ensure representative samples.

7.2.1. Parameters and Analytical Methods

Monitoring parameters were selected by Ecology as those expected to meet basic, enhanced, and phosphorus treatment goals and their known presence in stormwater, their potential for adverse impacts, or their value in providing necessary supporting information (see Section 3.3 for additional information). Table T-28 and Table T-29 list the parameters and selected analytical methods.

All water quality samples will be analyzed for the following parameters:

- Total suspended solids,
- Particle size distribution,
- pH,
- Total phosphorus,
- Ortho-phosphate,
- Hardness,
- Copper, total and dissolved, and
- Zinc, total and dissolved.

The sediment samples will be analyzed for the following parameters:

- Bulk density, [3]

- Grain size,
- Percent total solids,
- Total volatile solids,
- Total phosphorus,
- Total recoverable metals (cadmium, copper, lead, and zinc), and
- Total petroleum hydrocarbons (diesel fraction and oil fraction).

7.2.2. Sampling Techniques and Types

Sampling techniques and types to be used include automatic flow-weighted composite sampling of stormwater and manual grab collection of sediment samples.

Samples collected in water will be collected using automatic flow-weighted composite sampling. Sediment samples will be collected using manual grab procedures.

7.2.3. Qualifying Sample Criteria

The TAPE protocol (Ecology 2008) defines "representative" storms that must be monitored when ascertaining performance of treatment BMPs. Storm event criteria are established to: (1) ensure that adequate flow will be discharged; (2) allow some build-up of pollutants during the dry weather intervals; and (3) ensure that the storm will be "representative," (i.e., typical for the area in terms of intensity, depth, and duration).

Collection of samples during a storm event meeting these criteria ensures that the resulting data will accurately portray the most common conditions for each site. Ensuring a representative sample requires two considerations: (1) the storm event must be representative, and (2) the sample collected must represent the storm event.

Table 14 lists the qualifying storm event criteria to ensure the storm event sampled is representative. The number of samples needed to be representative is estimated to be 30 (see Section 6.1 for additional details).

Table 14. Qualifying storm event criteria.

Criteria	Requirements
Target storm depth	A minimum of 0.15 inches of precipitation over a 24-hour period
Rainfall duration	Target storms must have a duration of at least one hour
Antecedent dry period	A period of at least 6 hours preceding the event with less than 0.04 inches of precipitation.
End of storm	A continuous 6-hour period with less than 0.04 inches of precipitation.

Table 15 describes the criteria to ensure the composite sample collected is representative of the storm event sampled.

Table 15. Qualifying sampler collection criteria.

Storm event duration	<24 hours	>24 hours
Minimum storm volume to sample	75 percent of the storm event hydrograph	75 percent of the hydrograph of the first 24 hours of the storm
No. of Aliquots	At least 10 flow-weighted sub-samples (or aliquots) must be collected during the duration of the event. If fewer than 10, but 7 or more aliquots are collected, then the sample will be considered valid only if all other sampling criteria have been met.	
Maximum time period for sample collection (hours)	36	36

7.3. Monitoring Strategy

To facilitate flow monitoring, a primary measuring device (e.g., v-notch weir, compound weir, or Thel-Mar volumetric weir) will be installed in association with the monitoring stations. When weirs are used to measure flow, a stilling well will be connected to the primary measuring device to house a sensor (i.e., Instrumentation Northwest PS9805 submersible pressure transducer) for measuring water depth in the primary measuring device.

To facilitate remote access to the data from each station, each data logger will be equipped with telemetery systems (Airlink Raven 100 digital cellular modem). Using this system, it will be possible to view and upload the data from each station via an internet based interface. Power to the data loggers and sensors will be provided by 12-volt deep cycle marine battery that is continually charged with a 65 watt solar panel. Alternatively, a dedicated 120-volt, alternating current (AC) power source will be installed at selected sites to facilitate continuous operation of the data logger and sensors. The data loggers and associated telemetry systems will be housed in locking, vandal resistant enclosures (Knaack storage chests) that are hidden from public view to the extent possible.

Influent monitoring stations (designated CBSF1-In and CBSF2-In in Figure 5) will be established in each of the units to capture stormwater just prior to entering the influent sump. Similarly, effluent monitoring stations (designated CBSF1-Out and CBSF2-Out in Figure 5) will be established to capture treated and bypassed stormwater that collects in the effluent/bypass chamber just prior to leaving each unit via the outlet pipe.

Flow monitoring stations (designated CBSF1-FM and CBSF2-FM in Figure 5) will be established in the nearest down-gradient catch basins that receive treated and bypassed stormwater from CBSF1 and CBSF2. These flow monitoring stations will be used to pace automated samplers associated with both the influent and effluent monitoring stations for each unit in order to facilitate the collection of flow weighted composite samples. Because the Catch Basin StormFilters™ have a relatively low hydraulic residence time and do not infiltrate water, it is anticipated that the inlet and outlet hydrographs will be similar enough to warrant pacing the automated samplers for both the inlet and outlet stations using a single flow monitoring station in the outlet pipe for each unit.

Finally, flow monitoring stations (designated CBSF1-BP and CBSF2-BP in Figure 5) will be established in association with the bypass weir to measure the quantity of water that is bypassed around the filter cartridge chambers and subsequently enters the effluent/bypass chamber.

Data from all the monitoring stations described above will be processed to obtain pollutant load estimates for the inlet and outlet stations that are associated with CBSF1 and CBSF2. The treatment performance of each unit will subsequently be evaluated based on comparisons of loads and concentrations measured at these stations (i.e., CBSF1-In versus CBSF1-Out, and CBSF1-In versus CBSF1-Out.

Sediment monitoring stations will be established in connection with CBSF1 and CBSF2. The type, location, purpose, and sampling frequency for each of these stations are summarized in Table T-30. A total of three sediment monitoring stations will be established in connection with CBSF1 and CBSF2, respectively. The stations for CBSF1 (designated CBSF1-Sed-1, CBSF1-Sed-2, and CBSF1-Sed-3) will be used to monitor sediment accumulation rates and quality in the unit's influent sump and two filter cartridge chambers. Similarly, the stations for

CBSF2 (designated CBSF1-Sed-1, CBSF1-Sed-2, and CBSF1-Sed-3) will be used to monitor sediment accumulation rates and quality in these same locations.

7.3.1. Flow Monitoring

Stormflow rates will be continuously monitored at the following locations (see Figure 5):

- Bypass weir to measure volume of runoff that is not treated by the cartridges (Stations CBSF1-BP and CBSF2-BP)
- Effluent pipe to measure total flow through the system (Stations CBSF1-FM and CBSF2-FM).

Flow treated by each unit will be calculated by difference (FM minus BP).

7.3.1.1 Bypass Weir Flow Monitoring Equipment

Flow monitoring equipment will be identical at each site. Pressure transducers (Instrumentation Northwest Model PS9805, 0-1 psig) will be installed in a 3-inch PVC stilling chamber mounted on the upstream face of the bypass weir to monitor water depth in the treatment chamber. To provide more accurate measurement of lower flows, the unit's rectangular bypass weir will be converted to a compound weir by mounting a 45-degree V-notch weir plate at the base of the existing weir. Total bypass flow will be estimated as the sum of the flow though the V-notch and rectangular weirs using standard equations for V-notch and rectangular weirs (Grant and Dawson 1977):

Pressure transducers will be connected to Campbell Scientific CR800 data loggers to record water level measurements. Loggers will be programmed to record measurements every five (5) minutes. Each data logger will be equipped with an Airlink Raven 100 digital cellular modem to provide remote access to flow data. AC power will be supplied to each station. Monitoring equipment will be housed in Knaack Jobmaster Model 4830 storage chests (Appendix B). Enclosures will be installed on concrete pads located immediately adjacent to the CBSF1 and CBSF2 units. Transducer cables will be routed to the enclosures in 2-inch PVC pipe or 3/4-inch Liquid-Tite conduit.

7.3.1.2 Effluent Flow Monitoring Equipment

The 8-inch effluent pipes on each unit will be fitted with Thel-Mar removable weirs (Appendix B) to improve flow measurement accuracy. Polyethylene tubing (3/8-inch internal diameter) will be installed in the effluent chamber to facilitate water level measurements. One end will be mounted on the upstream face of the weir plate at the base of the 8-inch pipe and the other end will be installed inside a 3-inch PVC stilling chamber.

Flow rate will be estimated from water depth using standard equations for Thel-Mar weir (Grant and Dawson 1977).

Pressure transducers (Instrumentation Northwest Model PS9805, 0-1 psig) will be installed in the stilling chamber to monitor water depth in the effluent pipe. Pressure transducers will be connected to Campbell Scientific CR800 data loggers to record water level measurements. Loggers will be programmed to record measurements every five (5) minutes. Each data logger will be equipped with an Airlink Raven 100 digital cellular modem to provide remote access to flow data.

AC power will be supplied to each station. Transducer cables will be routed to the equipment enclosures in 2-inch PVC pipe or 3/4-inch Liquid-Tite conduit.

7.3.2. Water Quality Monitoring

To facilitate water quality sampling associated with this study, ISCO 6712 full size automated samplers (see detailed description in Appendix B) will be installed in association with the influent and effluent monitoring stations. Vinyl sampler suction tubing (3/8 inch ID) will be routed from each automated sampler to the point of sample collection. The suction tubing will be installed with a continuous positive slope from the point of sample collection to the pump head of the associated automated sampler. This will ensure proper draining of the suction tube during automated sampler purging cycles. A strainer will be installed at the terminus of the sampler suction tubing at the point of sample collection to prevent debris from clogging the tubing. The sampler intakes will be carefully positioned to ensure the homogeneity and representativeness of the samples. Specifically, sampler intakes will be installed to ensure that an adequate depth will be available for sampling and to avoid the capture of litter, debris, bed load, and other gross solids that may be present.

Samplers will be installed at the influent/effluent monitoring stations to collect flow-weighted composite samples:

- Influent sample station (Stations CBSF1-In and CBSF2-In). The sampler intake will be positioned to sample runoff prior to entering the influent sump. The sample tube will be mounted in a stainless steel tray suspended beneath the metal grating installed on the influent sump (Figure 6). Runoff from the surrounding area will enter and overflow the tray before entering the influent sump. Sediment that accumulates in the tray will be removed prior to each monitoring event.
- Effluent sample station (Stations CBSF1-Out and CBSF2-Out). The sampler intake will be installed in the effluent/bypass chambers at each site. Care will be taken to position the intakes so that they do not become covered by sediment that accumulates in the chamber.

Automatic samplers will be housed in the equipment enclosures described in Section 7.3.1. Sampler suction tubing will be routed from the collection point to the enclosures in buried 2-inch PVC pipe or ¾-inch Liquid Tite conduit.

7.3.3. Sediment Sample Collection

Sediment accumulation and sediment quality will be monitored in each chamber of the CBSF at each site to quantify the mass and chemical characteristics of particulates removed in each unit :

1. Influent chamber (Stations CBSF1-Sed1 and CBSF2-Sed1)
2. Filter chamber (Stations CBSF1-Sed2 and CBSF2-Sed2)
3. Effluent chamber (Stations CBSF1-Sed3 and CBSF2-Sed3).

Sediment accumulation rates will be measured manually in each chamber after each storm event and at the end of each year (prior to cleaning the unit); samples will be collected once each year over the 3-year monitoring period. The amount of sediment that accumulates in the chamber will be used in conjunction with the TSS removal rates to estimate the total mass of particulate material removed by the CBSF units.

Element III. Sampling and Measurement Procedures

This element describes the sampling and measurement procedures needed to acquire those data necessary to meet the study goals and objectives and includes:

Section 8 – Sampling Procedures, and

Section 9 – Measurement Procedures.

8. SAMPLING PROCEDURES

The quality of data collected in an environmental study is critically dependent upon the quality and thoroughness of field sampling activities. General field operations, practices, and specific sample collection will be well planned and carefully implemented and follow specific Standard Operating Procedures (SOPs) that support the following field activities:

- Monitoring equipment installation and setup,
- Storm tracking and forecasting,
- automatic flow-weighted composite sampling,
- Sediment sampling,
- Equipment decontamination, and
- Equipment maintenance and calibration.

These SOPs will include requirements for training and documentation of activities, collection of field quality control samples, and description of "Clean Handling Techniques" where appropriate.

8.1. Equipment Decontamination Procedures

A brief description of decontamination procedures for each set of Equipment follows. Details of these procedures will be contained in the SOPs.

For all samples where applicable, commercially available pre-cleaned sample containers will be used, and the laboratory will maintain a record of certification from the suppliers. The sample container shipment documentation will record batch numbers for the containers. With this documentation, containers can be traced to the supplier, and container wash analysis results can be reviewed.

8.1.1. Water Sampling Equipment

All sampling equipment and containers will be prepared prior to the sampling event.

8.1.1.1 Sample Bottles

The laboratories will provide certified pre-cleaned containers when appropriate. Carboys used for water quality sampling will be cleaned by laboratory personnel prior to each sampling event using a four step process:

- Rinse with Liquinox detergent solution,
- Rinse with tap water,
- Rinse with reagent grade water,
- Rinse with two molar nitric acid rinse, and
- Rinse with reagent grade water.

8.1.1.2 Automatic Samplers

Any portion of the Isco sampler (including intake screen, intake tubing, pump tubing, sample containers), filters, or other materials coming into contact with sampled stormwater will be decontaminated prior to use or certified pre-cleaned from the equipment source.

SOPs will contain detailed procedures and equipment material requirements to avoid potential contamination of samples. The sampler intake tubes and screens will be cleaned once prior to installation of the samplers and prior to each sample event thereafter.

8.1.2. Sediment Sampling Equipment

All sediment sampling equipment, including the stainless steel trowels, scoops, buckets, and bowls, will be cleaned and decontaminated prior to each sampling event. The equipment decontamination procedure includes the following steps:

- Rinse with tap water to remove bulk material.
- Scrub with Liquinox detergent solution and rinse with tap water.
- Rinse with reagent grade water.
- Rinse with reagent grade methanol.

8.2. Sample Collection and Monitoring Procedures

This section describes the sampling procedures that will be employed during performance monitoring of the Catch Basin StormFilters™. It begins with a description of the specific sampling procedures and monitoring procedures, presents procedures that will be used for sample handling and custody, and finishes with non-direct measurements.

General procedures for the following activities are described below:

- Flow monitoring,
- Water quality sampling,
- Sediment sampling, and
- Sediment accumulation monitoring.

Specific details of equipment selection and installation are described above in Section 7.

8.2.1. Precipitation and Flow Monitoring

As described above in Section 7, flows will be monitoring continuously at influent and effluent monitoring stations over the 3 year duration of this study (February 2009 – February 2012). In addition, precipitation depths will also be monitored continuously, using RG14, part of the SPU rain gauge network. Specific details regarding the monitoring equipment that will be installed in connection with each BMP are presented in Section 7.3.1.

Site installations will be thoroughly documented and a site diagram will be developed for each installation and documented in the Implementation Plan (see Table 12). Appropriate measurements will be collected when the equipment is installed to ensure monitoring accuracy (e.g., elevations of transducers relative to primary measurement devices such as weirs). All equipment will be tested prior to installation to ensure that sensors are accurately measuring water levels in accordance with manufacturer's specifications.

One week after the equipment is installed at a particular station, field personnel will visit the station to confirm that the equipment was installed correctly and is functioning as designed. After this initial check, field personnel will perform monthly site visits to upload data, check and replace batteries as necessary, visually inspect all system components, and perform calibration checks as necessary (see Section 10.2.3). Any operational problems that are identified during these site visits will be addressed immediately. Field personnel will use standardized field forms to document maintenance, calibration, and troubleshooting activities (see example form in Appendix A).

Data from each station will be uploaded on a weekly basis and after major storm events using the installed telemetry systems. The data will then be exported to a Microsoft Access database for all subsequent data management tasks (see Section 11). At this time, the data will also undergo a quality assurance audit (see Section 12). Any operational problems that are identified through this audit will be addressed immediately.

Data from SPU's existing rain gage RG14 (Figure 1) will be used to characterize rainfall conditions at the two BMP monitoring sites. RG14, a tipping bucket gage, is located less than one mile from either station and is expected to provide representative rainfall measurements. Rainfall is recorded in 0.01 inch increments.

8.2.2. Water Quality Sampling

As described above in Section 7, water quality sampling will be performed at influent and effluent monitoring stations during discreet storm events that occur over the 3 year duration of this study (February 2009 – February 2012). The goal of this sampling is to collect flow-weighted composite samples during 8 to 12 storm events in each year to obtain up to 30-paired influent and effluent samples at each BMP by the end of this period. This section describes in detail the sampling procedures that will be used to meet this goal.

8.2.2.1 Storm Event Forecasting and Pre-Event Procedures

The key part of any stormwater sampling program is monitoring and forecasting storm events to ensure that field personnel are prepared and field equipment are deployed in advance of the event. The Implementation Plan and Communication Plan (see Table 12) will clearly identify the decision path, lines of communication, and authority.

Antecedent conditions and storm predictions will be monitored via the Internet, and a determination will be made as to whether to target an approaching storm for sampling. The speed and intensity of incoming storm events will then be tracked using Internet-accessible images from publicly available Doppler radar.

Once a decision has been made to target a storm event for sampling, field personnel will conduct site visits to deploy clean sample bottles in the automated samplers at each site, calibrate equipment as necessary, clear any obstructions from the sampler intakes, and check the operational status of the flow monitoring equipment.

8.2.2.2 Storm Sampling Procedures

Field personnel will then fill the automatic samplers with ice and initiate the sampler program. (Ice is estimated to keep the interior of the samplers cool for 48 hours; consequently, ice will not be added to the samplers more than 24 hours before a targeted storm event.)

The volume used to pace the automated samplers will be determined in advance of the storm event based on rainfall versus runoff relationships that are developed using linear regressions of precipitation and runoff volume data that were collected during previous storm events. Using these relationships, runoff volume for each station will be estimated based on the forecasted rainfall total for the targeted storm event. The estimated runoff volume (cubic feet) will then be divided by 45 (the median number of 100 mL aliquots that the 9.4 L polyethylene carboy will hold) to estimate the sample pacing (cubic feet) volume necessary to collect a 9.4 L composite sample. The rainfall versus runoff relationships will be continually updated throughout the duration of the study to reflect changing hydrologic conditions.

The Campbell Scientific data loggers described above in conjunction with the hydrologic monitoring will be programmed to record cumulative storm volume at each station and send a 400-millisecond, 5-volt pulse to the associated automated samplers at preset volume intervals. Each automated sampler will be programmed to collect 100 milliliter (mL) sample aliquots into a 9.4-liter (L) polyethylene carboy when triggered by the data logger. The automated samplers will be programmed to perform one rinse cycle prior to actual sample collection in order to reduce the likelihood of cross contamination between successive aliquots.

Flows and sample collection times will be monitored remotely using the telemetry systems associated with each data logger (see description in previous section).

8.2.2.3 Post-Event Procedures

After the storm event, storm event criteria identified in Section 7.2.3 for storm event (Table 14) and sample representativeness (Table 15) will be assessed prior to sample retrieval by analyzing hydrologic and sampling recorded for each station. If the storm event criteria have not been met, the samples will be discarded and the associated bottles sent to the laboratory for cleaning in preparation for the next storm event. If the criteria have been met, field personnel will remove the chilled 9.4-L polyethylene carboys and place them in coolers. Ice will then be added to the coolers to keep the sample temperatures within the carboys below 6 degrees Celsius. The carboys will then be transported to the laboratory within the allowable limits for sample holding times (see Table T-31). In general, the laboratory will be notified at the onset of each sampling event to ensure that adequate laboratory staff will be available to process the incoming samples. Once in the laboratory, water from the containers will be used to fill pre-cleaned, preserved (where appropriate) sample bottles for the required analyses.

8.2.3. Sediment Sampling

As described above in Section 7, sediment samples will be collected annually from each chamber of the CBSF over the 3-year monitoring period. Whenever possible, sediment samples will be collected using a stainless steel scoop mounted to an extension pole to avoid confined space entry. If adequate sample cannot be collected using the scoop, field personnel will enter the appropriate chamber of the CBSF and collect samples using a stainless spoon or trowel.

Sediment sampling procedures will generally follow Puget Sound Estuarine Program procedures (PSEP 1997). Sampling procedures are described below:

(1) If needed, remove standing water from the appropriate CBSF chamber using a pump and discharge to the nearest maintenance hole downstream of the site.

(2) Collect grab samples from 4-5 locations at each sampling station using a stainless steel scoop or spoon as described above. Place each sample aliquot into a stainless steel bowl. Nitrile gloves will be worn at all times while handling/collecting the sample.

(3) Homogenize the contents of the bowl using a stainless steel spoon. Remove any debris (e.g., cigarette butts, wood chips) and discard. Remove any sediment particles

greater than 2 centimeters in diameter and place in a separate container for subsequent weighing to determine total mass of sediment removed by the BMP.

(4) Decant free standing liquid from the bowl prior to filling sample bottles.

(5) Label bottles and record field observations (e.g., sediment depth and depth of water, if any, in the CBSF chambers, condition of the filter cartridges, presence/absence of oil or other contaminants in the CBSF) and sample characteristics (e.g., visible sheen, odors, color, soil classification) in the field notebook.

(6) Transport to the laboratory within the allowable limits for sample holding times (see Table T-32).

As described in Section 7, three sediment monitoring stations will be established in connection with CBSF1 and CBSF2, respectively. The stations for CBSF1 (designated CBSF1-Sed-1, CBSF1-Sed-2, and CBSF1-Sed-3) will be used to monitor sediment accumulation rates and quality in the unit's influent sump and two filter cartridge chambers. Similarly, the stations for CBSF2 (designated CBSF1-Sed-1, CBSF1-Sed-2, and CBSF1-Sed-3) will be used to monitor sediment accumulation rates and quality in these same locations.

The sediment samples for each of these stations will be derived from three subsamples that are obtained from different locations in the influent sump and two filter cartridge chambers, respectively. These subsamples will subsequently be composited in a single stainless steel bowl and processed in accordance with the procedures outlined above.

8.2.4. Sediment Accumulation Monitoring

As described in Section 7, the amount of sediment that accumulates in each chamber of the CBSF will be measured after each storm event and at the end of each year to quantify the mass of particulate material removed by the BMP. A tape measure will be used to measure from the top of the unit to the surface of the sediment layer and to the bottom of the structure in each chamber. Measurements will be taken at five locations in each chamber (center, north, south, east, and west sides of the opening). Values will be averaged to determine the average depth of sediment in the structure. Sediment volume will be estimated using the average depth and the dimensions of each chamber.

The depth measurements will be used along with the inspection protocol to determine if the CBSF require maintenance during the 3-year monitoring period (see Section 7.1). If so, the maintenance standard developed by the manufacturer and adopted by SPU may be triggered.

8.3. Sample Handling & Custody

Sample handling and custody procedures ensure that uniquely identifiable samples are transported to the analytical laboratory with appropriate preservation within prescribed holding times and with proper documentation. Written documentation of sample custody from the time of sample collection through the generation of data by analysis of that sample is recognized as a vital aspect of an environmental study. The chain-of-custody of the physical sample and its corresponding documentation will be maintained throughout the handling of the sample by following the procedures outlined below.

8.3.1. Sample Identification

All samples will be clearly labeled in the field with indelible ink. Each sample will be uniquely identified by its sample location identifier (see Table 6), the date and time stamp, and the sample matrix. For composite samples, the date and time stamp will reflect the last aliquot collected.

The combination of the sample location identifier, date and time stamp, and matrix provided on the Electronic Data Deliverable (EDD) by the analytical laboratory will provide the index that links the sample event data and field data, which will identify storm event data and field duplicate samples where applicable.

8.3.2. Sample Transportation

The sample teams will collect the stormwater from the automated samplers or collect grab samples, place the samples on ice, and transport them as soon as possible to the selected analytical laboratory.

8.3.3. Sample Preservation

Other than ice, sample preservation will not be required in the field. Composite samples will be chilled with ice as they are collected. Grab samples must be chilled immediately following collection.

Chemical preservatives are added to the samples for certain analyses to prolong the stability of the parameters during transport and storage. Table T-31 lists the required sample preservatives for the analytical parameters. If composite sampling procedures are used, no preservatives are added to the composite container because no single chemical preservative is suitable for all of the parameters to be analyzed. The laboratory must first divide the composite sample into the appropriate bottle for each analysis, and then add chemical preservatives as appropriate for each analysis. If manual grab sampling procedures are used (i.e., monitoring personnel directly fill the containers required for each analysis), the monitoring personnel will add the appropriate preservative to each sample container immediately.

8.3.4. Sample Processing

In general, all samples will be minimally processed in the field to prevent potential contamination from trace pollutants in the atmosphere. Samples will be transported to the analytical laboratory as soon as possible after sample collection. The Study Manager will coordinate with the analytical laboratory to ensure samples can be transported, received, and processed during non-business hours if needed.

Sample filtration is required when collecting samples for dissolved metals determinations. Filtration for metals will be conducted by the analytical laboratory to reduce the potential for contamination in the field, especially during storm conditions.

Once the samples have been delivered to the laboratory, the laboratory staff will transfer the sample from the carboy to the appropriate bottles for the required analytical procedures (see Table T-28 and Table T-29). During this process, the carboy will be vigorously agitated to ensure that a representative sample will be transferred to each bottle. In order to minimize exposure of the samples to human, atmospheric, and other potential sources of contamination, laboratory staff will process the samples using “clean” techniques pursuant to protocols developed by the U.S. EPA (1996) for the low-level detection of metals.

8.3.5. Holding Times

All samples will be transported to the laboratory within the allowable limits for sample holding times (see Table T-31 and Table T-32). Once in the laboratory, samples will be processed and stored as required by the analytical method (Table T-28 and Table T-29).

Holding times are short for some parameters. For composite samples, the "sample collection time" used to evaluate holding time limits, is the time that the final sample aliquot is collected. To minimize the risk of exceeding holding times, the Study Manager will coordinate with the analytical laboratory prior to each event to ensure that the laboratory is prepared to begin processing samples as soon as samples are received. In addition, samples will be delivered to the laboratory immediately after retrieval from field samplers.

8.3.6. Chain of Custody Forms

A chain of custody form (see example in Appendix A) will accompany each sample batch that is delivered to the laboratory. The purpose of chain-of-custody (COC) forms is to keep a record of the sample submittal information and to document the transfer of sample custody. Standard COC forms will be prepared for the study that will include sample location identifier, analyses to be requested, and any special considerations, such as analyses priority order and sample filtration needs. At the time of sample collection, the field team will record the sample date and time, sample location, matrix, and analyses requested. Any special instructions for the laboratory will also be noted on the COC form such as specifications of quality control requirements (e.g., duplicate samples). The COC form must be signed by both the person relinquishing the samples and the person receiving the samples every time the samples change hands, thus documenting the chain of custody.

The study quality assurance officer will review a copy of the signed chain-of-custody form to ensure that all required analytical procedures have been identified for the laboratory and all sample holding time requirements have been met.

8.4. Non-direct Measurements

Precipitation will be collected under the existing Seattle Public Utilities hydrological program. This data, which is managed by the Hydrological Project Manager, follows Standard Operating Procedures for data collection, validation, and management to ensure it is of known and documented quality.

9. MEASUREMENT PROCEDURES

Laboratory analytical procedures will follow methods approved by the U.S. Environmental Protection Agency (APHA et al. 1992; U.S. EPA 1983; U.S. EPA 2007). The analytical methods, preservation methods, container specifications, holding times, and detection limits for water quality samples are presented in Table T-28 and Table T-31; the same information is also provided for sediment samples in Table T-29 and Table T-32.

The laboratories that will be selected for this study will be certified by Ecology and participate in audits and interlaboratory studies conducted by Ecology and U.S. EPA. The adequacy of the standard operating procedures in the laboratories has been verified by these performance and system audits.

Within 30 days of receiving the samples, the laboratory will report the analytical results in standardized reports that will include sample and quality control data. The reports are suitable for evaluating the study data and also will include a case narrative that summarizes any problems encountered during the analyses.

Element IV. Study Implementation QA/QC Procedures

This element describes the procedures to be followed during the study implementation phase and includes:

Section 10 – Quality Control, which discusses measures to be implemented in the analytical laboratory and field,

Section 11 – Data Management and Documentation, a quality assurance (QA) measure to ensure maintenance of accurate and complete records of all study activities, and

Section 12 – Audits and Reports, which ensures the QAPP is implemented as described in this Plan.

10.QUALITY CONTROL

To ensure the data quality objectives for this study are met, quality control procedures are identified in separate sections below for analytical and field activities. The overall objective of these procedures is to ensure that data of a known and acceptable quality are collected for this study.

10.1. Analytical Quality Control

Laboratory analytical quality control (QC) procedures involve the use of four basic types of QC samples (Table 16). QC samples are analyzed within a batch of client samples to provide an indication of the performance of the entire analytical system. Therefore, QC samples go through all sample preparation, clean up, measurement, and data reduction steps in the procedure. In some cases, the laboratory may perform additional tests that check only one part of the analytical system. Please refer to the Glossary for a definition of each laboratory QC sample and Table T-26. MQOs for parameters to be measured in water.Table T-26Table T-27 for MQOs for each QC sample.

Table 16. Laboratory Quality Control Samples by Matrix.

QC Sample	Matrix	Frequency of Analysis
Matrix Spike (MS)	Water	One of each per batch of 20 or fewer samples of similar matrix.
Laboratory (or Matrix) Duplicate (MSD)	Water Sediment	One of each per batch of 20 or fewer samples of similar matrix.
Method or Preparation Blank (MB)	Water Sediment	One of each per batch of 20 or fewer samples of similar matrix.
Laboratory Control Samples (LCS)	Sediment	One of each per batch of 20 or fewer samples of similar matrix.

Laboratory duplicates for each parameter will be analyzed for a randomly selected sample with every sample batch. Data for batch samples (i.e., samples from other studies analyzed with samples from this study) will be acceptable as long as duplicates are analyzed at a frequency of at least 5 percent.

10.2. Field Quality Control

The following procedures will be used during field activities to ensure that data quality objectives will be met.

10.2.1. QC Samples

The following quality assurance samples will be collected in the field in addition to the regular samples previously identified for this study.

10.2.1.1 Equipment Rinsate Blanks

Equipment rinsate blanks will be collected to verify that the automated sampler tubing is not a source of contamination. In order to collect the sample, the sampler suction tubing will be detached at the point of sample collection and placed in a carboy of reagent grade water. The sampler will be programmed to collect 9.0 L of reagent grade water using normal sample collection procedures. The number of rinsate blanks to be collected during the sampling season is reported in Table T-33. All rinsate blank samples will be submitted to the laboratory and labeled as separate (blind) samples. Additionally, sample intake tubing will be replaced after each monitoring year.

10.2.1.2 Field Duplicates

To facilitate collection of the field duplicate, BMP influent automated samplers will be outfitted with a sample distribution arm and rack that holds four 3.8 L polyethylene bottles. The field duplicate sampler will be programmed to distribute four separate 100-mL sample aliquots into each of the four bottles at predefined flow increments. At the end of the storm event, the contents of two of the 3.8 L bottles will be combined into a clean, 9.4 L carboy that will be submitted as the primary sample for the station. The contents of the remaining two 3.8 L bottles will be combined into a separate 9.4 L carboy that will be submitted as the field duplicate for the station. All field duplicates will be submitted to the laboratory and labeled as separate (blind) samples. Field duplicates will be collected at a minimum frequency of 10 percent. The resultant data from these samples will then be used to assess any variation in the analytical results that is attributable to environmental (natural), sample handling, and analytical variability.

Field duplicates of sediment will be prepared as splits by filling two sets of sample jars with homogenized material from one bowl containing a composite sample of sediment. One field duplicate will be prepared with every sample batch collected on an annual basis, which will provide approximately one field duplicate for every 10 samples. The field duplicates will be identified by a unique number that does not indicate the origin of the material (i.e., blind to the laboratory).

10.2.2. Instrument/Equipment Calibration and Frequency

The calibration of all monitoring equipment will also be checked on a regular basis. The specific calibration procedures and frequency that will be applied to the discharge, water level, and precipitation monitoring equipment, respectively, are described in the following subsections.

Site visits will be made to check the calibration of the water level monitoring equipment at each BMP at a minimum frequency of six times annually. During each site visit, field personnel will make a manual measurement of the water level at each monitoring station from a permanently established reference point and then immediately note the monitoring equipment's reading. The difference between these two values will be tracked over time by means of control charts to detect potential instrument drift and other operational problems. This information will also be used to assess the MQOs that are identified for hydrologic data in Table T-24. Corrective actions will be implemented if the data do not meet the specific MQOs that have been defined for each objective.

At sites equipped with Thel-Mar weirs, field personnel will also establish new offsets for the associated pressure transducers at a minimum frequency of four times annually. (The offset depth is used to convert the actual readings from a pressure transducer to an estimate of the water depth over the Thel-Mar weir's crest.) During this process, field personnel will install a temporary inflatable bladder in the conveyance pipe with the Thel-Mar weir at a location immediately up-gradient of the weir. The space in the pipe between the bladder and the weir will then be filled with water to a depth that is equal to the crest of the Thel-Mar weir. This depth will be recorded and programmed into the data logger as the new offset for the pressure transducer at the station.

11. DATA MANAGEMENT PROCEDURES

This section discusses data management, which addresses the path of data from recording in the field or laboratory to final use and archiving. The data management and documentation strategy combines the use of Standard Operating Procedures (SOPs) that specify documentation needs and provide for consistency when collecting, assessing, and documenting environmental data and electronic storage of all documents and records on servers that are regularly backed up.

Documents will be archived in portable document format (pdf) on the City of Seattle's Science Information Catalog (SIC), an Oracle Portal-based document library. Data will be managed and archived in the City's Science Information Management System (SIMS), an Oracle-based information management system. These documents will be retained for a minimum of 5 years.

11.1. Documents and Records

Four types of documentation will be managed: (1) field operation records; (2) laboratory records; (3) data handling records and (4) Plan revision documentation.

11.1.1. Field Operation Records

Field operation records may include:

Water quality sampling - During each pre- and post-storm site visit to each monitoring station for water quality sampling, the following information will be recorded on a waterproof standardized field form (see Appendix A):

- Site Name
- Date/time of visit and last sample collected
- Name(s) of field personnel present
- Weather and flow conditions
- Sampler battery voltage
- Logger battery voltage
- Rain gauge condition, if applicable
- Desiccant condition
- Number of aliquots (if sampled)
- Sampling errors? (if sampled)
- Sample duplicate? (if sampled)
- Estimated sample volume (if sampled)
- Log of photographs taken
- Presence of obstructions in primary measurement device or sample tubing and remedial actions taken

- Unusual conditions (e.g., oily sheen, odor, color, turbidity, discharges or spills, and land disturbances)
- Deviations from approved sampling procedures

Sediment monitoring - During site visits made for sediment sampling related to this study, field personnel will record the following information on a waterproof standardized field form:

- Date and time of sample collection or visit
- Name(s) of sampling personnel
- Weather conditions
- Number and type of samples collected
- Location of each sample
- Sediment depth at each sample location
- Color, odor, and grain size characteristics of each sample
- Log of photographs taken
- Unusual conditions (e.g., water color or turbidity, presence of oil sheen, odors, and land disturbances).
- Deviations from approved sampling procedures

11.1.2. Laboratory Records

Laboratory records will include a statement of work, data package, and electronic data deliverable, which are described below:

Statement of Work (SOW): A list of specifications and requirements with which analytical laboratories must meet in order to do work.

Data Package: A hardcopy and electronic (pdf format) report from an analytical laboratory on a single set of chemical analyses, which contains the material specified in the SOW and sufficient documentation to allow an appropriate professional, at a substantially different time and location, to ascertain:

- what analyses were performed and what results were obtained,
- that the data had acceptable properties (such as accuracy, precision, method reporting limits),
- where, when, and by whom the analyses were performed,
- that the analyses were done under acceptable conditions (such as calibration, control, custody, using approved procedures, and following generally approved good practices), and that the SOW was otherwise followed.

The data package will report the test results clearly and accurately. The test report will include the information necessary for interpretation and validation of data and will include the following:

- Report title,
- Name and address of laboratory,
- Name and address of client and study name,
- Subcontractor results clearly identified,
- Description and unambiguous name of tested sample,
- Date and time of sample collection, date of sample receipt, and date and time of analysis,
- Preservation at time of sample acceptance (temperature, pH, etc.),

- Identification of test method,
- QC results for method blank, MS/MS duplicates, LCS, as appropriate,
- An explanation of failed QC and any non-standard conditions that may have affected quality,
- A signature and title of laboratory director or designee, and.
- Chain of Custody and sample receipt forms.

Electronic Data Deliverable (EDD): The data will be provided in a computer-compatible file that is delivered from the analytical laboratory in the SOW-specified format via Internet, e-mail, or compact disk from which analytical chemistry data may be uploaded directly into databases.

11.1.3. Data Handling Records

This section describes the approach for record control and storage of each sampling event. All documents associated with a sampling event will be stored electronically. Paper copies will not be archived. Each sampling event will be documented with the following records:

- Field Datasheet,
- Chain of Custody (COC),
- Field QA Report,
- Data Package,
- Data Validation Memo,
- Electronic Data Deliverable (EDD) with Quality & Usability Flags.

All documents will be provided in portable document format (pdf) with the exception of the flow reports and the EDD, which will be in Excel® format. These documents will be uploaded to the Science Information Catalog (SIC) and referenced in the Science Information Management System (SIMS). The EDD with quality and usability qualifiers will be uploaded to SIMS. Table T-35 summarizes the data path for each sampling event and outlines the roles and expected timeline.

11.2. Revisions to the QAPP

In the event that significant changes to this QAPP are required prior to the completion of the study, a revised version of the document shall be prepared and submitted to the Principle Investigator for review. The approved version of the QAPP shall remain in effect until the revised version has been approved.

Expedited Changes to the QAPP should be approved before implementation to reflect changes in study organization, tasks, schedules, objectives, and methods, address deficiencies and non-conformance, improve operational efficiency and accommodate unique or unanticipated circumstances. Requests for expedited changes are directed from the Study Manager to the Principle Investigator in writing. They are effective immediately upon approval by the Principle Investigator and Quality Assurance Coordinator, or their designees, and any regulatory authority if needed.

Justifications, summaries, and details of expedited changes to the QAPP will be documented and distributed to all persons on the QAPP distribution list by the Principle Investigator. Expedited changes will be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.

12. AUDITS AND REPORTS

This section discusses assessment, response actions, and corrective actions to ensure all data is being collected as described in this Plan.

12.1. Assessments and Response Actions

Field, analytical, and data management activities are evaluated based on the schedule below.

Table 17. Assessment and response action schedule.

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Laboratory Inspections	Dates to be determined	QA Coordinator	Analytical and quality control procedures employed at the laboratory and the contract laboratory	30 days to respond in writing to address corrective actions.
Monitoring Systems Audit	Dates to be determined	QA Coordinator	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP and may include: field sampling; handling and measurement; facility review; and data management as they relate to the study.	30 days to respond in writing to address corrective actions.
Site Visit	Dates to be determined	Study Manager	Status of activities. Overall compliance with work plan and QAPP	As needed.

12.2. Deficiencies, Nonconformances and Corrective Action

The Study Manager is responsible for implementing and tracking corrective action procedures because of audit findings. Records of audit findings and corrective actions are maintained by both the QA Coordinator and Study Manager.

If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in the laboratory's Quality Management Plan (QMP) and in agreements or contracts between participating organizations.

Deficiencies are defined as unauthorized deviation from procedures documented in the QAPP. Nonconformances are deficiencies that affect quality and render the data unacceptable or indeterminate.

Deficiencies related to sampling methods requirements include, but are not limited to, such things as sample container, volume, and preservation variations, improper/inadequate storage temperature, holding-time exceedances, and sample site adjustments.

Deficiencies related to chain-of-custody include but are not limited to delays in transfer, resulting in holding time violations; incomplete documentation, including signatures; possible tampering of samples; broken or spilled samples, etc.

Deficiencies related to field and laboratory measurement systems include but are not limited to instrument malfunctions, blank contamination, quality control sample failures, etc.

Deficiencies related to Quality Control include but are not limited to quality control sample failures.

Deficiencies are documented in logbooks, field data sheets, etc. by field or laboratory staff and reported to the cognizant field or laboratory supervisor who will notify the Study Manager. The Study Manager will notify the QA Coordinator of the potential nonconformance within 24 hours, who will then initiate a Nonconformance Report (NCR) to document the deficiency.

The Study Manager, in consultation with QA Coordinator (and other affected individuals/organizations), will determine if the deficiency constitutes a nonconformance. If it is determined that the activity or item in question does not affect data quality and therefore is not a valid nonconformance, the NCR will be completed accordingly, and the NCR closed. If it is determined a nonconformance does exist, the Study Manager in consultation with QA Coordinator will determine the disposition of the nonconforming activity or item and necessary corrective action(s); results will be documented by the contractor QA Coordinator by completion of a Corrective Action Report.

Corrective Action Reports (CARs) document: root cause(s); programmatic impact(s); specific corrective action(s) to address the deficiency; action(s) prevent recurrence; individual(s) responsible for each action; the timetable for completion of each action; and, the means by which completion of each corrective action will be documented. CARs will be included with quarterly progress reports. In addition, significant conditions (i.e., situations that, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to the Principle Investigator immediately both verbally and in writing.

Element V. Assessment Procedures

This element describes the assessment procedures implemented after data collection is complete to determine if the data conform to the specified criteria and will satisfy the study objectives and if so, the analysis and format for presentation of the results. It includes:

Section 13 - Data Validation & Verification,

Section 14, Data Quality (Usability) Assessment, and

Section 15 – Data Analysis and Presentation.

Sections 13 and 14 describe the procedures used to determine if the MQOs established in Section 6.2 for the six data quality indicators (PARCCS - precision, accuracy (bias), representativeness, completeness, comparability, and sensitivity) have been met.

The result of sections 13 and 14 are data of known and documented quality, we answer the question; *are the data of sufficient quality and quantity to meet the use for which they are intended*.

13. DATA VERIFICATION AND VALIDATION

This section discusses the procedures that will be used during the verification and validation review of hydrologic, water quality, and sediment data. It begins with an overview of the process and then presents more detailed information on the specific procedures to be employed during the actual review.

This section discusses data review, verification, and validation. Analytical data will be reviewed, verified, and validated using a Tier I data review level (Table 18).

Table 18. Data review levels.

Tier	Description
Tier I – Compliance Screening[11]	Includes evaluation of package completeness; sample chain-of-custody; sample preservation and analytical holding times; blank contamination; precision (replicate analyses); accuracy (compound recovery); target analyte list, and detection limits.
Tier II – Summary Validation[12]	Includes evaluation of all QC elements from Compliance Screening plus instrument performance (initial calibration, continuing calibration, tuning, sensitivity and degradation.
Tier II – Full Validation[13]	Includes evaluation of all QC elements from Summary Validation plus evaluation of compound identification and quantitation (transcription and calculation checks).

13.1. Data Review, Verification, and Validation

Data verification involves examining the data to ensure that they are consistent, correct, and complete (Ecology 2004). Furthermore, data verification is performed to confirm that the methods and protocols specified in the QAPP were followed. Data validation is an analyte-specific and sample-specific review that extends beyond the verification process to determine the analytical quality of a specific data set. It involves a detailed examination of the data to

[11] Also referred to as: cursory; verification/CCS (EPA); QA-1 (PSDDA/PSEP);Tier I (EPA Region I).
[12] Also referred to as: Level 3 (EPA CLP); Level C (Navy);Screening (AFCEE)' M-2 (organic EPA Region 3); IM-2 (inorganic EPA Region 3); Tier II (EPA Region 1); CLP summary form review.
[13] Also referred to as: Levels 4 or 5 (EPA CLP); Levels D or E (Navy); QA-2 (PSDDA/PSEP); Definitive (AFCEE); Tier III (EPA Region 1); M-3 (organic EPA Region 3); IM-3 (inorganic EPA Region 3).

confirm whether the specific MQOs that were established for the study (see Section 6) were met. The Quality Assurance Coordinator will be responsible for overseeing the verification and validation process to ensure that all data used in subsequent analyses and reporting meet the quality assurance objectives for the study.

13.2. Verification and Validation Methods

Procedures used to validate and verify data will be described in a SOP, which will also include roles, responsibilities, and documentation. Table T-24 summarizes the data verification elements that will be assessed, the criterion to be met, and the action to be taken should the criterion not be met. Table T-36 lists the data qualifier codes that may be used as indicators of data qualify.

All data will be verified to ensure they are representative of the samples analyzed and locations where measurements were made, and that the data and associated quality control data conform to study specifications. The data verification procedures will generally include:

- Storm event verification (i.e., did the sampling event meet the established storm criteria, Table 14);
- Sample verification (i.e., was a valid flow-paced sample collected over the appropriate storm volume, Table 15);
- Field QC (did we collect at appropriate frequency and did they meet the established control limits); and
- Laboratory QA/QC (did lab meet established control limits).

14. DATA QUALITY (USABILITY) ASSESSMENT

This section describes the process for determining the data usability, the method for data reduction, and the process for assessing the data quality. The methods and procedures that will be used to determine if the DQOs and MQOs established in Section 6.0 have been met and to prepare presentation of the study results are discussed. The purpose of this process is to determine: *if the decision (or estimate) can be made with the desired confidence, given the quality of the data set?*

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose.

Data reduction is the process of converting raw data to results. Study-specific data reduction methods are designed to ensure that data are accurately and systematically reduced into a usable form.

Data Quality Assessment (DQA) is the scientific and statistical evaluation of data to determine if data obtained from environmental data operations are of the right type, quality, and quantity to support their intended use.

14.1. Data Usability Assessment

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose. Three levels or classes of data quality are used:

- **Accepted** Data conform to all requirements, all quality control criteria are met, methods were followed, and documentation is complete.

- **Qualified** Data conform to most, but not all, requirements, critical QC criteria are met, methods were followed or had only minor deviations, and critical documentation is complete.

- **Rejected** Data do not conform to some or all requirements, critical QC criteria are not met, methods were not followed or had significant deviations, or critical documentation is missing or incomplete. The results are unusable.

The usability assessment includes assessment of potential outliers, confirmation that the data is comparable and representative, and calculation of the completeness:

- Identification of outliers from the previous quarter's data collection efforts,
- Confirmation of outliers from previous data collection efforts when sufficient data is available to complete the outlier test,
- Confirmation of the comparability of the data, and
- Confirmation of the representativeness of the data.

Definitions for each DQI can be found in the Glossary as well as the equation for calculating completeness. Specific methodology for completing the data usability assessment is discussed below.

14.1.1. Data Processing Guidelines

Some additional data processing may be required prior to performing any data usability or data reduction functions. Anticipated data processing needs are described below. Any additional needs will be included in the Quarterly Usability Report (see Section 14.1.4).

Handling of non-detected values. The analytical laboratory will be requested to report an estimated value for all non-detected results as well as identifying each as such. In the event an estimated value below the reporting limit is not provided, the value will be estimated at half of the reporting limit.

Handling of field duplicates The primary field duplicate sample will be used in the data assessment process.

14.1.2. Identification of Outliers

Outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected.

The evaluation and handling of potential outliers will be performed using the guidance found in the EPA document "Guidance for Data Quality Assessment", EPA/600/R-96/084. Section 4.4 of the EPA document provides guidance on identifying potential outliers, choosing the proper statistical test, evaluating the results and documenting the process.

Documentation of the outlier designation will include:

- The rationale for the choice of the outlier test along with the results,
- the supporting scientific facts to demonstrate that the outlier is not just a statistical anomaly, but was in fact a true outlier, and

- The impact the outlier data point had on the statistical processing of the data.

14.1.3. Descriptive Statistics

At a minimum, the following resistant measures will be developed to describe the measured concentrations for each parameter:

- Measure of location – median,
- Measure of spread – interquartile range (IQR), and
- Measure of skewness - quartile skew coefficient (q_s).

14.1.4. Roles, Responsibility, and Documentation

The Study Manager and/or Principle Investigator will document the Usability Assessment by preparing a quarterly report, which includes:

(1) Listing of all data collected for the period. Include any usability flags qualifying the data.

(2) Summary for the study data collected to date including:

- Descriptive statistics,
- Performance to date, and
- Progress at meeting the statistical goal (see Section 6.1).

14.2. Data Assessment Approach, Methods, and Presentation

Data analyses will be performed to evaluate the water quality treatment performance of each of the monitored BMPs following procedures identified by Ecology (2008) in G*uidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE)*, and the U.S. EPA (2002b) in *Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements*. The specific procedures that will be used in these analyses are follows:

- Statistical analyses to compare influent and effluent concentrations and loads.
- Calculation of pollutant removal efficiency.
- Calculation of “achievable” pollutant removal efficiency.
- Calculation of “relative” pollutant removal efficiency.
- Calculation of pollutant removal efficiency based on regression of influent and effluent pollutant loads.
- Comparisons of the cumulative probability distribution for influent and effluent pollutant concentrations and loads.

Each of these procedures is described in more detail in the following subsections.

14.2.1. Statistical Comparisons of Influent and Effluent Concentrations and Loads

Statistical analyses will be performed to assess significance of differences in pollutant concentrations and loads between the influent and effluent stations across individual storm events. The specific null hypothesis (H_o) and alternative hypothesis (H_a) for these analyses are as follows:

Ho: *Effluent pollutant concentrations and loads are equal to or higher than influent concentrations and loads.*

Ha: *Effluent concentrations and loads are lower than influent concentrations and loads.*

To evaluate these hypotheses, a Wilcoxon signed rank test (Helsel and Hirsch 1992) will be used to compare performance data from each paired station (i.e., influent versus effluent at each BMP). As noted above, the Wilcoxon test is a non-parametric analogue to the paired t-test. Statistical significance will be assessed based on an alpha (α) level of 0.05.

14.2.2. Calculation of the Pollutant Removal Efficiency.

Pursuant to guidance from Ecology (2008), pollutant removal efficiencies will be estimated using the three methods described below.

Method #1: Individual Storm Reduction in Pollutant Concentration

The reduction (in percent) in pollutant concentration during each individual storm (ΔC) will be calculated as:

$$\Delta C = 100 \times \frac{\left(C_{in} - C_{eff}\right)}{C_{in}}$$

Where:

C_{in} = flow-weighted influent pollutant concentration, and
C_{eff} = flow-weighted effluent pollutant concentration.

Method #2: Aggregate Pollutant Loading Reduction

The aggregate reduction (in percent) in pollutant load for all storms (ΔL_{agg}) will be calculated as:

$$\Delta L_{agg} = 100 \times \frac{\left(\sum_{i=1}^{n}\left(C_{i,in} * V_i\right) - \sum_{i=1}^{n}\left(C_{i,eff} * V_i\right)\right)}{\sum_{i=1}^{n}\left(C_{i,in} * V_i\right)}$$

Where:

$C_{i,in}$ = influent pollutant concentration for storm *i*,
V_i = volume of storm *i*,
$C_{i,eff}$ = flow-weighted effluent pollutant concentration, and
n = number of storms.

Method #3: Individual Storm Reduction in Pollutant Loading

Pollutant load reduction (in percent) in individual storms (Δ*L*) will be calculated as:

$$\Delta L = 100 \times \frac{\left(\left(C_{in} \times V\right) - \left(C_{eff} \times V\right)\right)}{\left(C_{in} \times V\right)}$$

Where:

C_{in} = flow-weighted influent pollutant concentration, and
V_i = volume of storm *i*, and
C_{eff} = flow-weighted effluent pollutant concentration.

15. DATA ANALYSIS & PRESENTATION

This section discusses the content of the Annual Stormwater Monitoring Report, which covers data collected during the previous water year. Each Annual Stormwater Monitoring Report, which is an attachment to the Annual Report under the Phase I Permit, is required to include the following four elements (Permit Section H.1.a):

1) A summary including the BMP type location, land use, drainage area size, and hydrology for each site.
2) The status of implementing the monitoring program,
3) A comprehensive data and QA/QC report for each part of the monitoring program, with an explanation and discussion of the results of each monitoring study, and
4) Performance data.

These requirements are discussed below in three sections that will likely provide the outline for the report; a site summary, a comprehensive data summary, and a QA/QC summary.

15.1. Site Summary & Status

The site summary and status will include a summary of the study and the current status.

- **Site Summary** The “summary including the BMP type location, land use, drainage area size, and hydrology for each site” is a brief description of the more detailed information presented in this QAPP. Additionally, the following information, if applicable, will be included in this section of the Annual Stormwater Monitoring Report:
    - ❖ Describe any land use changes in the drainage basin that would potentially affect hydrology or pollutant loading.
    - ❖ Indicate hydrologic information if a monitoring site is subject to base flow from groundwater or is tidally influenced. Describe backwater conditions or other site-specific conditions if they influence sampling.
    - ❖ Describe any preliminary conclusions regarding BMP effectiveness. Ecology recognizes that it may be too early to draw conclusions depending upon study design.
- **Status**

- A description of any changes made to the sampling program. Significant changes must be documented in a revised QAPP.
- A narrative description of status as of the end of the reporting period and statement as to when the program will be completed, if appropriate.
- A physical description of the BMP for the reporting period, such as damage, maintenance actions or repairs.
- Based on the monitoring activities up through the reporting period, the status of meeting the statistical goal, including an estimate of the remaining number of samples needed to meet these statistical performance measures.

15.2. Comprehensive Data Summary

The comprehensive data report will include at a minimum:

- **Stormwater sampling results**
  - A table or descriptive summary indicating whether the sampled storm events met the requirements listed in Table 14and Table 15.
  - For each storm event at each site, a summary or graph of the following:
    - Time versus precipitation,
    - Time versus flow rate, and
    - Time versus initiation of aliquot collection.
  - Tables showing qualified analytical results from each sampling event.
  - Tables showing hydrological information for each measured event:
    - Total precipitation (inches),
    - Influent, effluent, and bypass peak flow rate (gpm), and
    - Total influent, effluent, and bypass volume (gallons).
  - Tables showing sampling information for each measured event:
    - Number of influent and effluent aliquots,
    - Influent and effluent EMCs for each parameter monitored.
- **Sediment sample results**
  - Tables showing qualified sediment quality data.
- **Performance results**
  - Tables showing performance data for each event that has usable paired data.

15.3. Quality Assurance/Quality Control Summary

The QA/QC summary will include at a minimum:

- A data validation memo for each sampling event that includes: (a) a narrative analysis of appropriate *field quality control* procedures *data quality indicator results* and of any associated issues and corrections made and (b) a narrative analysis of appropriate laboratory quality control procedures with measurement quality objectives discussed, any associated issues and corrections made.
- A summary Quality Assurance Report, which includes:
  - A narrative summarizing the data validation memos that apply to the entire reporting period.
  - An overall assessment of the usability and representativeness of the data.
  - A summary description of any planned changes or deviations from the approved QAPP to address problems encountered during QA/QC.

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List of Revisions

The current list of revisions for this QAPP follows.

Revision Number	Effective Date	Review Status	Revised by	Revision Summary
R0D1	11/5/2007	Draft	Shelly Basketfield	Initial draft.
R0D2	2/10/2008	Draft	Shelly Basketfield	Added Section 7 through 14 from Herrera Environmental Consultants, Inc.
R0D3	5/16/2008	Draft	Rex Davis	Incorporation of Ecology's comments.
R0D4	09/09/2008	Draft	Shelly Basketfield	Changed QAPP scope to CatchBasin StormFilters only. Previously included bioswales also. Addressed Ecology's comments regarding BMP performance.
R1D0	02/12/2009	Draft	Shelly Basketfield/Doug Hutchinson	Incorporated Ecology's comments of 09/26/2008.

Tables

Table T-19. Quality assurance planning document cross-walk.

Washington Department of Ecology	Environmental Protection Agency
1. Title Page with Approvals	A1 Title and Approval Sheet
2. Table of Contents and Distribution List	A2 Table of Contents A3 Distribution List
I. Goals and objectives of the study	
3. Background	A5 Problem Definition/Background
4. Project Description	A6 Project/Task Description
5. Organization and Schedule	A4 Project/Task Organization
II. Type, quality, and quantity of data needed	
6. Quality Objectives	A7 Quality Objectives and Criteria for Measurement Data
7. Sampling Process Design (Experimental Design)	B1 Sampling Process Design (Experimental Design)
III. Sampling and measurement procedures to acquire those data	
8. Sampling Procedures	B2 Sampling Methods B3 Sample Handling and Custody
9. Measurement Procedures	B4 Analytical Methods
IV. Study implementation QA/ QC procedures to ensure Plan is followed	
10. Quality Control	B5 Quality Control B6 Instrument/Equipment Testing, Inspection, and Maintenance B7 Instrument/Equipment Calibration and Frequency B8 Inspection/Acceptance of Supplies and Consumables
11. Data Management Procedures	B10 Data Management
12. Audits and Reports	C1 Assessments and Response Actions C2 Reports to Management
IV. Assessment procedures to ensure that study objectives are met	
13. Data Verification and Validation	D1 Data Review, Verification, and Validation D2 Verification and Validation Methods
14. Data Quality (Usability) Assessment	D3 Reconciliation with User Requirements
15. Data Analysis and Presentation	

Table T-20. Standard Operating Procedure List (draft).

Field Category	SOP No.	Standard Operating Procedure
BK- Background	BK 1000	General
	BK 2000	Laboratory Process
QC – Quality Control	QC 1000	General
	QC 2000	Documentation
	QC 3000	Data Verification and Validations
	QC 4000	Procedure Specific QA/QC
	QC 5000	Alternative Methods
	QC 6000	Data Management
	QC 7000	Data Requests
SD-Sample Design	SD 1000	Site Selection
	SD 2000	Field Plan & Mobilization
DS – Discrete Sampling	DS 1000	Surface Water Sampling
	DS 2000	Stormwater Sampling (includes field cleaning and clean techniques)
FM – Field Measurements	FM 1000	pH
	FM 2000	Specific Conductance
	FM 3000	Temperature
	FM 4000	Dissolved Oxygen
	FM 5000	Turbidity
CM - Continuous Monitoring	CM 1000	Discharge
	CM 2000	Automatic Samplers
	CM 3000	Sediment Traps

Table T-21. National Stormwater BMP Database requirements for all BMPs.

Element	CBSF1	CBSF2
General Test Site Information		
Location	California Ave SW & SW Spokane St	California Ave SW & SW Manning St
City	Seattle	Seattle
State	Washington	Washington
zip Code	98124	98124
Country	USA	USA
Altitude	374	376
Watershed Information		
Watershed Name	Puget Sound	Puget Sound
Total Watershed Area (acres)	0.18	0.23
Percent (%) Impervious Area	100	100
Regional Climate Station	SPU RG14	SPU RG14
Land Use Information	Arterial	Arterial
Monitoring Station		
Station	CBSF1	CBSF2
Identify Upstream BMP	NA	NA
Identify Relationship to Upstream BMP	NA	NA
Identify Relationship to Downstream BMP	NA	NA
Monitoring Instrumentation		
Monitoring Station Name	CBSF1	CBSF2
Precipitation Data		
Monitoring Station Name	RG14	RG14
Storm Runoff and Base Flow Data		
Monitoring Station Name	CBSF1	CBSF2
Type of Flow	TBD	TBD
Flow Start Date	TBD	TBD
Total Bypass Volume (if any)	TBD	TBD
Total Storm Flow Volume into or from BMP	TBD	TBD
Dry Weather Base Flow Rate	TBD	TBD
Water Quality Sampling Event		
Monitoring Station Name	CBSF1	CBSF2
Related Flow-Event	TBD	TBD
Date Water Quality Sample Collected	TBD	TBD
What medium does the Instrument Monitor	TBD	TBD
Water Quality Parameters	TBD	TBD
Unit Qualifier	TBD	TBD

Table T-22. National Stormwater BMP Database requirements for structural BMPs.

Element	Value
BMP Name	Catch Basin StormFilter
BMP Type	Structural
Date Facility was placed into service	2006
Number of Separate Inflows	1
Describe the Type and Design of each BMP outlet	Treated effluent from the StormFilters™ and bypassed stormwater both commingle in the effluent/bypass chamber and are subsequently discharged out of the system via an 8-inch outlet pipe.
Is the BMP designed to bypass when full?	Yes
BMP Drawing (plan view and profile)	Figure 4, Figure 5, Figure 6

Table T-23. National Stormwater BMP Database requirements for structural BMPs.

Element	Value
Permanent pool volume, upstream of filter media (if any)	11.6 cubic feet (1'-7"L x 2'-8"W x 2'-9"D)
Permanent pool surface area (ft2)	3.1 sq. feet (1'-2"L x 2'-8"W)
Permanent pool length (ft)	2
Surcharge detention volume (ft3)	NA
Surface detention volume surface area	NA
surcharge detention volume's design drain times	NA
Surcharge detention volume design depth	NA
Media filter surface area (ft2)	7.5 sq. feet per cartridge (cartridge hydraulic loading rate of 1 gpm/ft2 of media surface area x 7.5 gpm/cartridge)
Angle of sloping or vertical filter	The CBSF floor shall slope ¼ inch maximum across the width and slope downstream 1 inch per foot of length.
Number of media filter layers	2
Describe depth and type of each filter media layer	Each cartridge contains a total of approximately 2.6 cubic feet of media. The ZPG™ cartridge consists of an outer layer of perlite that is approximately 1.3 cubic feet in volume and an inner layer, consisting of a mixture of 90% zeolite and 10% granular activated carbon, which is approximately 1.3 cubic feet in volume. **Perlite Media**: Perlite media shall be made of natural siliceous volcanic rock free of any debris or foreign matter. The expanded perlite shall have a bulk density ranging from 6.5 to 8.5 lbs per cubic foot and particle sizes ranging from 0.09" (#8 mesh) to 0.38" (3/8" mesh). **Zeolite Media**: Zeolite media shall be made of naturally occurring clinoptilolite. The zeolite media shall have a bulk density ranging from 44 to 50 lbs per cubic foot and particle sizes ranging from 0.13" (#6 mesh) to 0.19" (#4 mesh). Additionally, the cation exchange capacity (CEC) of zeolite shall range from approximately 1.0 to 2.2 meq/g. **Granular Activated Carbon**: Granular activated carbon (GAC) shall be made of lignite coal that has been steam-activated. The GAC media shall have a bulk density ranging from 28 to 31 lbs per cubic foot and particle sizes ranging from a 0.09" (#8 mesh) to 0.19" (#4 mesh).

Table T-24. Data Quality Indicators and their MQO criteria.

Data Verification Element	Data Quality Indicator (DQI)	Evaluation	MQO (criterion)	Action [14]
Compliance	Bias	Field and Method Blanks	<RL Table T-26, Table T-27	If [Field blank] >2x RL or [Method blank]>RL; Apply "J" to all affected samples if the [sample] <5xRL. Apply "B" to all affected samples if the [sample] ≥5xRL.
		Laboratory Control Sample (%R)	Table T-26, Table T-27	Apply "R" to all affected samples if the %R ≥2xMQO. Apply "J" to all affected samples if the MQO > R% <2xMQO.
	Repeatability	Field Duplicate (RPD)	25% water/35% soil	Apply "R" to all affected samples if the RPD ≥ 2 x MQO. Apply "J" to all affected samples if MQO < RPD < 2 x MQO.
	Precision	Laboratory Duplicate (RPD)	Table T-26, Table T-27	Apply "R" to all affected samples if the RPD ≥ 2 x MQO. Apply "J" to all affected samples if MQO < RPD < 2 x MQO.
	Accuracy	Matrix Spike Recovery (%R)	Table T-26, Table T-27	Apply "R" to all non-detected value samples if %R <30%. Apply "J" to all affected samples if MQO < %R < MQO (spike recovery limits do not apply when sample concentration exceeds the spike concentration by a factor of 4 or greater).
		Discharge	Table T-25	Apply "J" to all affected storm events.
		Water Level	Table T-25	Apply "J" to all affected storm events
		Precipitation	Table T-25	Apply "J" to all affected storm events
	Sensitivity	Reporting Limits (RL)	Table T-28, Table T-29	Apply "J" to all affected samples (reported as <RL) if the reported RL≤ 2 times specified RL. Apply "R" to all affected samples if the reported RL is >2 times the specified RL.
Complete-ness	Completeness	Analytical data	90%	Estimate of the amount of successfully collected data versus the amount intended (based on MQOs) in the experimental design. If percent of useable data collected over a year period (the water-year) < criterion the MQO was not met.
		Hydrologic data	90% of data record is present	Completeness will be assessed on the basis of the occurrence of gaps in the data record for all monitoring equipment.

[14] In the case of laboratory QC samples, the affected samples typically means the batch. See Table T-36 for data qualifier code definitions.

Table T-24 (continued) Data Quality Indicators and their MQO criteria.

Data Verification Element	Data Quality Indicator (DQI)	Evaluation	MQO (criterion)	Action
Correctness	Representative-ness	Qualitative Assessment of methodology	Analytical Methods (Table T-28 and Table T-29) Field methods (Section 8)	Representativeness is maintained by following procedures such as complying with a statistically-based field sampling design and proper sample homogenization. If sampling and analytical methods did not conform to established plans and methods the MQO for representativeness may not have been met. Any deviations from these methodologies must be approved in writing by the PI in accordance with the procedures outlined in Sections 11.1.3. Deviations that are deemed unacceptable will result in rejected values (R).
		Qualitative Assessment of Holding time & Preservation	Table T-31, Table T-32	Apply "J" to all samples that exceeded the holding time by <48 hours. Apply "R" to all samples that exceeded the holding time by ≥48 hours
		Qualitative Assessment of storm event sampled	Table 14	Did the sampling event meet the established storm criteria?
		Qualitative Assessment of sampler performance	Table 15	Did the sampler collect a valid flow-paced sample and capture the appropriate storm volume?
		Qualitative Assessment of specified storm event criteria	Table 14	Does the storm event criteria specified represent typical site conditions? See Smoley (1993). Is the monitoring conducted over a sufficient period to represent climatic conditions for the site?
Consistency	Comparability	Qualitative Assessment	Adequate	Expected level of confidence with which data sets from different sources (e.g., related projects, different analytical methods, different sampling locations, or sampling teams) can be compared to one another. If sampling and analytical methods did not conform to established plans and methods, the MQO for comparability may not have been met.

Table T-25. MQOs for hydrologic monitoring.

Monitoring Equipment	Measurement Type	MQO for Percent Bias	Manufacturer Specified Operational Range	Manufacturer Specified Accuracy
Marsh-McBirney Flo-Tote 3	Discharge	≤20% when velocity/water level is between 10 and 90% of operational range ≤35% when discharge is <10% or >90% of operational range	Velocity: -5 to +20 ft/s Water level: 0.4 to 138 inches	: ±5% of reading, assumes pipe 10-90% full
Instrumentation Northwest PS9805	Water Level	≤10%	0 to 2.31 feet	±0.1% of full span (0-1 psi) or ±0.002 feet
Hydrologic Services CS700 tipping bucket rain gauge	Precipitation Depth	≤5%	0 to 27.6 inches/hour	±2% for rainfall intensities ranging from 1 to 19.6 inches/hour

ft/s: feet per second

Table T-26. MQOs for parameters to be measured in water.

Parameter	Laboratory Method Blank [a]	Field Equipment Rinsate Blank [a]	Control Standard Recovery	Matrix Spike Recovery [b]	Laboratory Duplicate *RPD* [c]
Total suspended solids	Not to exceed the reporting limit	NA	90-110%	NA	≤25% or ±2 × RL
Particle Size Distribution	NA	NA	NA	NA	≤20% or ±2 × RL
pH (laboratory)	NA	NA	NA	NA	≤5%
Total phosphorus	Not to exceed the reporting limit	Not to exceed 2x of the reporting limit	90-110%	75–125%	≤20% or ±2 × RL
Ortho-phosphorus	Not to exceed the reporting limit	Not to exceed 2x of the reporting limit	90-110%	75–125%	≤20% or ±2 × RL
Hardness	Not to exceed the reporting limit	NA	90-110%	75–125%	≤20% or ±2 × RL
Copper, dissolved	Not to exceed the reporting limit	Not to exceed 2x of the reporting limit	90-110%	75–125%	≤20% or ±2 × RL
Copper, total	Not to exceed the reporting limit	Not to exceed 2x of the reporting limit	90-110%	75–125%	≤20% or ±2 × RL
Zinc, dissolved	Not to exceed the reporting limit	Not to exceed 2x of the reporting limit	90-110%	75–125%	≤20% or ±2 × RL
Zinc, total	Not to exceed the reporting limit	Not to exceed 2x of the reporting limit	90-110%	75–125%	≤20% or ±2 × RL

[a] If criteria is not met associated blank concentration is defined as the new reporting limit and study sample data within 5 times this de facto reporting limit are flagged with a *J*.
[b] For inorganics, the Contract Laboratory Program Functional Guidelines state that the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of four or more (Ecology 2005).
[c] The relative percent difference must be less than or equal to the indicated percentage for values that are greater than 5 times the reporting limit. RPD must be and ±2 times the reporting limit for values that are less than or equal to 5 times the reporting limit.
mg/L = milligrams per liter.
µg/L = micrograms per liter.
NA = not applicable.
RL = reporting limit.
RPD = relative percent difference.

Table T-27. MQOs for parameters to be measured in sediment

Parameter	Laboratory Method Blank [a]	Control Standard Recovery	Matrix Spike Recovery [b]	Surrogate Recovery	Laboratory Duplicate *RPD* [c]
Percent total solids	NA	NA	NA	NA	≤20% or ±2 × RL
Grain size	NA	NA	NA	NA	≤20% or ±2 × RL
Bulk density	NA	NA	NA	NA	≤20% or ±2 × RL
Total volatile solids	Not to exceed the reporting limit	NA	NA	NA	≤20% or ±2 × RL
Petroleum hydrocarbons - Diesel Petroleum hydrocarbons - Oil	Not to exceed the reporting limit	50–90%	38–99%	50-122%	
Total phosphorus	Not to exceed the reporting limit	80-120%	75–125%	NA	≤20% or ±2 × RL
Cadmium, total Copper, total Lead, total Zinc, total	Not to exceed the reporting limit	80-120%	75–125%	NA	≤20% or ±2 × RL

[a] If criteria is not met, associated blank concentration is defined as the new reporting limit and study sample data within 5 times this de facto reporting limit are flagged with a *J*.
[b] For inorganics, the Contract Laboratory Program Functional Guidelines state that the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of four or more (Ecology 2005).
[c] The relative percent difference must be less than or equal to the indicated percentage for values that are greater than 5 times the reporting limit. RPD must be and ±2 times the reporting limit for values that are less than or equal to 5 times the reporting limit.
[d] Reporting limits for sediments are reported as dry weight; study sample reporting limits may be elevated due to high moisture content or high contaminant concentrations.
mg/kg = milligrams per kilogram
TPH: total petroleum hydrocarbons.
NA = not applicable.
RL = reporting limit.
RPD = relative percent difference.

Table T-28. Sensitivity MQOs in stormwater collected by automatic sampler [15].

Analyte Group	Parameter	Units	Methodology	Analytical Method [16]	Reporting Limit Target (Appendix 9) [17]	Method Detection Limit [18]	Method Reporting Limit [19]
Conventional	Hardness (total)	mg/L CaCO3	Titrimetric (EDTA)	SM2340-B or C	1		1
	Particle Size Distribution		Sieve and laser diffraction	TAPE [20]	NA		0.1%
	pH	s.u.	Electrometric	SM 4500 - H^+ B	0.2		0.2
	Total Suspended Solids (TSS)	mg/L	Non-Filterable Gravimetric, Dried at 103-105°C	SM2540-D	1		1
Metals (dissolved & total)	Copper	ug/L	ICP/MS	EPA 200.8	0.1	0.02	0.5
	Zinc	ug/L	ICP/MS	EPA 200.8	1.0 dissolved/ 5.0 total	0.1	4.0
Nutrients	Orthophosphate	as P mg/L	Ion chromatography	SM4110-B	0.01		0.01
	Phosphorus, Total	as P mg/L	Persulfate digestion followed by manual or automatic ascorbic acid reduction	Manual (SM 4500-P E) or Automatic (SM 4500-P F)	0.01		0.02

Table T-29. Sensitivity MQOs in sediment [15].

Analyte Group	Parameter	Units	Analytical Method	Reporting Limit Target (Appendix 9)	Method Detection Limit	Method Reporting Limit
Conventional	Bulk Density	g/cm^3		NA		0.01
	Grain size	%	ASTM D422	NA		0.1%
	Solids, Total	%	EPA160.3 or SM2540B	NA		0.01%
	Solids, Volatile	mg/kg	SM2540E	NA		5
Metals	Cadmium	mg/kg	EPA 200.8 or 6020	0.1	0.2	0.2
	Copper	mg/kg	EPA 200.8 or 6020	0.1	0.2	0.5
	Lead	mg/kg	EPA 200.8 or 6020	0.1	0.3	1.0
	Zinc	mg/kg	EPA 200.8 or 6020	5.0	0.7	4.0
Nutrients	Phosphorus, Total	as P mg/kg	Manual (SM 4500-P E) or Automatic (SM 4500-P F)	NA		0.4
Total Petroleum Hydrocarbons (TPH)	Diesel Range Organics - Diesel	mg/kg	NWTPH-Dx - Ecology, 1997, (Publication No. 97-602) or EPA SW-846 method 8015B	25.0 -100.0		25
	Diesel Range Organics - Oil	mg/kg				10

[15] These parameters will be analyzed by an accredited laboratory per Chapter 173-50 WAC.
[16] A single method will be noted after selection of the analytical laboratory.
[17] Based on method detection limits or method performance.
[18] Results that fall between the MRL and MDL as not quantifiable and results that fall below the MDL are considered non-detects.
[19] The method reporting limit (MRL) is 3 to 10 times the MDL. Or the value the laboratory can meet.
[20] Method used for particle size distribution analyses will follow procedures identified in Appendix F of Ecology's *Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE)*.

Table T-30. Type, location, purpose, and sampling frequency for monitoring stations to be established in the Catch Basin StormFilters™ located on California Avenue SW.

Station	Station Type	Station Location	Station Purpose	Sampling Frequency
CBSF1-In	Water quality	CBSF1 at entrance to influent sump.	Monitor stormwater influent quality to CBSF1.	Sampling during 10 storm events annually.
CBSF1-Out	Water quality	CBSF1 at entrance to influent sump.	Monitor stormwater effluent quality from CBSF1.	Sampling during 10 storm events annually.
CBSF1-FM	Discharge	In 8-inch outlet pipe for CBSF1 in catch basin located at the southeast corner of California Avenue SW and SW Spokane Street	1. Monitor stormwater effluent and bypass quantity from CBSF1. 2. Pace automated sampler during collection of flow-weighted composite samples at the CBSF-In and CBSF-Out stations.	Continuous monitoring (5-minute logging interval).
CBSF1-BP	Discharge	Influent sump for CBSF1 at location behind bypass weir.	Monitor stormwater bypass quantity from CBSF1.	Continuous monitoring (5-minute logging interval).
CBSF2-In	Water quality	CBSF2 at entrance to influent sump.	Monitor stormwater influent quality to CBSF2.	Sampling during 10 storm events annually.
CBSF2-Out	Water quality	CBSF2 at entrance to influent sump.	Monitor stormwater effluent quality from CBSF2.	Sampling during 10 storm events annually.
CBSF2-FM	Discharge	In 8-inch outlet pipe for CBSF2 in catch basin located at the southeast corner of California Avenue SW and SW Manning Street.	1. Monitor stormwater effluent and bypass quantity from CBSF2. 2. Pace automated sampler during collection of flow-weighted composite samples at the CBSF-In and CBSF-Out stations.	Continuous monitoring (5-minute logging interval).
CBSF2-BP	Discharge	Influent sump for CBSF2 at location behind bypass weir.	Monitor stormwater bypass quantity from CBSF2.	Continuous monitoring (5-minute logging interval).
CBSF1-Sed-1	Sediment characterization	Influent sump for CBSF1.	Monitor sediment mass accumulation rates and quality.	Annual sediment sampling and depth measurements (Dec. 2009, Dec. 2010, and Dec. 2011).
CBSF1-Sed-2		South filter cartridge chamber for CBSF1.		
CBSF1-Sed-3		North filter cartridge chamber for CBSF1.		
CBSF2-Sed-1		Influent sump for CBSF2.		
CBSF2-Sed-2		South filter cartridge chamber for CBSF2.		
CBSF2-Sed-3		North filter cartridge chamber for CBSF2.		

Table T-31. Preservation and holding times for water quality analyses.

Parameter	Field Sample Container	Pre-Filtration Holding Time [b]	Total Holding Time [b]	Field Preservation	Laboratory Preservation
Total suspended solids	9.4 L HDPE Carboy	7 days	7 days	Maintain ≤ 6°C	Maintain 4°C
Particle size distribution		7 days	7 days		Maintain 4°C
pH		15 minutes [b]	15 minutes [b]		Maintain 4°C
Total phosphorus		NA	28 days		Maintain 4°C, H_2SO_4 to pH < 2
Ortho-phosphorus		15 minutes [b]	48 hours		Maintain 4°C, H_2SO_4 to pH < 2
Hardness as $CaCO_3$		NA	6 months		Maintain 4°C, HNO_3 to pH < 2
Copper, dissolved		15 minute [b]	6 months		Maintain 4°C, HNO_3 to pH < 2 after filtration
Copper, total		NA			Maintain 4°C, HNO_3 to pH < 2
Zinc, dissolved		15 minute [b]			Maintain 4°C, HNO_3 to pH < 2 after filtration
Zinc, total		NA			Maintain 4°C, HNO_3 to pH < 2

[a] SM method numbers are from APHA et al. (1998); EPA method numbers are from U.S. EPA (1983; 2007).
[b] Holding time specified in U.S. EPA guidance (U.S. EPA 1983; U.S. EPA 2007) or referenced in APHWA et al. (1992) for equivalent method. Fifteen minute holding times for dissolved metals, ortho-phosphate and pH cannot realistically be met with flow-weighted automated sampling techniques. Consequently, a surrogate holding time of 24 hours will be used for the purposes of this study.
C = Celsius.
mg/L = milligrams per liter.

Table T-32. Preservation and holding times for sediment analyses.

Parameter	Sample Container	Pre-Processing Holding Time	Total Holding Time	Field Preservation	Laboratory Preservation
Grain size	16 oz glass jar	NA	6 months	Maintain ≤ 6°C	Maintain ≤ 4°C
Bulk density	8 oz glass jar	NA	6 months		
Percent total solids	8 oz glass jar	NA	6 months		
Total volatile solids		NA	6 months		
Total phosphorus		28 days	6 months		
Cadmium, Total		6 months	2 years		
Copper, total					
Lead, total					
Zinc, total					
Petroleum hydrocarbons - Diesel	8 oz glass jar	14 days	40 days		
Petroleum hydrocarbons - Oil					

Table T-33. Anticipated total number of samples and associated QA requirements for each water quality parameter.

Parameter	Samples per Station	Number of Stations	Total Number of Samples [a]	Laboratory Method Blanks [b]	Field Equipment Rinsate Blanks [c]	Laboratory Control Standard [b]	Matrix Spike [b]	Field Duplicates [d]	Lab Duplicates [b]
Catch Basin StormFilter - CBSF1									
Total suspended solids	10/year	2	60	1/batch	NA	1/batch	NA	2/year	1/batch
Particle size distribution	10/year	2	60	NA	NA	NA	NA	2/year	1/batch
pH	10/year	2	60	NA	NA	NA	NA	2/year	1/batch
Total phosphorus	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Ortho-phosphorus	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Hardness as $CaCO_3$	10/year	2	60	1/batch	NA	1/batch	1/batch	2/year	1/batch
Copper, dissolved	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Copper, total	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Zinc, dissolved	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Zinc, total	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Catch Basin StormFilter - CBSF2									
Total suspended solids	10/year	2	60	1/batch	NA	1/batch	NA	2/year	1/batch
Particle size distribution	10/year	2	60	NA	NA	NA	NA	2/year	1/batch
pH	10/year	2	60	NA	NA	NA	NA	2/year	1/batch
Total phosphorus	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Ortho-phosphorus	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Hardness as $CaCO_3$	10/year	2	60	1/batch	NA	1/batch	1/batch	2/year	1/batch
Copper, dissolved	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Copper, total	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Zinc, dissolved	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch
Zinc, total	10/year	2	60	1/batch	4/year	1/batch	1/batch	2/year	1/batch

[a] Assuming three year monitoring program duration.
[b] Laboratory QA samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.
[c] Equipment rinsate blanks will be collected at the beginning and in the middle of each monitoring year from each station.
[d] Field duplicates will be collected and analyzed for at least ten percent of the total number of submitted samples.
NA: not applicable.

Table T-34. Anticipated total number of samples and associated quality assurance requirements for each sediment parameter.

Parameter	Samples per Station [a]	Number of Stations	Total Number of Samples [b]	Laboratory Method Blanks [c]	Field Equipment Rinsate Blanks	Laboratory Control Standard [d]	Matrix Spike [c]	Field Duplicates [d]	Lab Duplicates [c]
Catch Basin StormFilter - CBSF1									
Percent total solids	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
Grain size	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
Bulk density	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
Total volatile solids	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
NWTPH-Dx -Diesel	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
NWTPH-Dx - Oil	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Total phosphorus	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Cadmium, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Copper, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Lead, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Zinc, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Catch Basin StormFilter - CBSF2									
Percent total solids	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
Grain size	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
Bulk density	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
Total volatile solids	1/year	2	6	NA	NA	NA	NA	1/year	1/batch
NWTPH-Dx -Diesel	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
NWTPH-Dx - Oil	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Total phosphorus	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Cadmium, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Copper, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Lead, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch
Zinc, total	1/year	2	6	1/batch	NA	1/batch	1/batch	1/year	1/batch

[a] One sample will be collected from each station at the end of each of the three monitoring year (for exception see note e).
[b] Assuming three years of monitoring.
[c] Laboratory QA samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.
[d] Field duplicates will be collected and analyzed for at least ten percent of the total number of submitted samples.
[e] During the first year of monitoring two sample sets will be collected, one before the beginning of monitoring and one at the end of the year.
NA: not applicable.

Table T-35. Sample data path.

Activity	Role	Process Duration (days)	Timeline (days) [21]	Document to Data Steward (cc PI)	Document from Data Steward (cc PI)
Target storm go/no go	Study Manager	7	-7	Forecast Storm Go/No Go Decision	NA
Collect samples & deliver to Lab	Field Lead	2	2	Field Datasheet & COC	NA
Precipitation Data Verification (by 10th of month)	Hydrologic Data PM	Up to 30	32	Storm Event - Precipitation Summary	NA
Flow Data Verification	Study Manager	Up to 10	32	Storm Event – Discharge Summary	NA
Field Data Verification	Study Manager	7	41	Field QA Report	All data submitted to Data Steward to Date
Laboratory Analyses	Lab PM	60	62	Data package, EDD	NA
Analytical review, verification, validation	Data Validation PM	Up to 21	83	Data Validation Memo, EDD with Quality Flags	Data Package, EDD, Field QA Report
Data entry to SIMs & SIC	Data Entry	Up to 7	90	NA	All data submitted to Data Steward to Date
Verify all data/reports/forms have been entered	Data Steward	Up to 2	92	Status Log	NA
Data Usability Assessment	Principle Investigator/Study Manager (TBD)	Up to 28	Quarterly	EDD with Usability Flags	All data submitted to Data Steward to Date
Data entry to SIMs & SIC	Data Entry	Up to 2	Quarterly	NA	EDD with Usability Flags

Table T-36. Study data qualifier flags.

Use	Flag	Description
Example Laboratory Data Indicator Flags	H	Holding time exceeded
	B	Analytes detected in associated method blank at a concentration greater than one half of the reporting limit or 5 percent of the regulatory limit or 5 percent of the analyte concentration in the sample
Verification & Validation Flags	R	The datum is rejected. The qualifier typically indicates that a datum is completely unusable because it is of unknown quality (e.g., missing QC information) or because of gross QC deficiencies (e.g., extremely poor recoveries for the LCS).
	J	The target analyte is positively identified, but the reported numerical result (e.g., analyte concentration) is an estimated value. The flag indicates that a significant quantitative (as opposed to a qualitative) uncertainty exists. The J flag must always be used to report detections below the method quantitation limit (MQL).
	U	Analyte not detected at the listed method reporting limit.
	S	The datum is tentatively rejected (suspect) because study-specific measurement quality objectives (e.g., for sensitivity, accuracy, or precision) were not met or were not demonstrated. When objectives for sensitivity are not met, the S flag typically indicates that a result (a detection or non-detection) is potentially unusable with respect to an action level (e.g., the result does not demonstrate that a target analyte is actually present in an environmental sample at a concentration above or below a risk-based decision limit). Note: When evaluating objectives for sensitivity, the R flag may be more appropriate than the S flag when action levels are fixed and statistical analyses are not being performed. The S flag may be appropriate when action levels are subject to change, a set of data is being evaluated with respect to different action levels, or when statistical analyses are being performed.
Usability Data Qualifiers	NR	Data was requested and not reported.
	J	The Identification of the analyte is acceptable, but quality assurance criteria indicate that the quantitative values may be outside the normal expected range of precision, i.e., the quantitative value is considered estimated.
	Q	Data is considered questionable and shall not be used until the acceptability of the data is confirmed or denied. This flag is usually used to qualify extreme values that are suspected to be outliers. Statistical analysis is used to confirm or deny that the suspected value is or is not an outlier. If the suspected value is confirmed to be an outlier, the data qualifier shall be changed to R.
	R	Data is considered to be rejected and shall not be used. This flag denotes the failure of quality control criteria such that it cannot be determined if the analyte is present or absent from the sample. Resampling and analysis are necessary to confirm or deny the presence of the analyte.

[21] Day 0 of the timeline is the beginning of a storm event.

Accuracy - Accuracy is defined as the degree of agreement of a measurement to an accepted reference or true value.

Analytical accuracy will be measured as the percent recovery (percent R) of an analyte in a reference standard or spiked sample. Accuracy (percent R) criteria for matrix spike recoveries and surrogate recoveries will be within limits specified in the QAPP. Accuracy shall be calculated as percent recovery of matrix spikes as follows:

$$R_I(\%) = \frac{Y_i}{X_i} x100\%$$

where:

% Ri	=	percent recovery for compound i
Yi	=	measured spike concentration in sample i (measured - original sample concentration)
Xi	=	known spike concentration in sample i

The resultant percent recoveries will be compared to the criteria specified in the QAPP and deviations from specified limits reported. If the objective criteria are not met, the laboratory will supply a justification of why the acceptability limits were exceeded and implement the appropriate actions. Percent recoveries will be reviewed during data validation, and deviations from the specified limits will be noted and the effect on reported data commented upon by the data reviewer.

Hydrologic data have no “true” results for comparison. For hydrologic data, accuracy will be assessed by comparison of results to repeat measurements using another instrument, engineering calculations, or to manufacturer specifications and expressed as bias:

$$\%Bias = \frac{\text{M - I}}{\text{I}} \times 100\%$$

where:

M	=	measured value
T	=	Independent (true value).

Discharge data – The independently measured value may be determined by measuring the cross-sectional area of flow at a particular station and the average flow velocity using a portable meter (e.g., Marsh-McBirney Flo-Mate). These data will then be processed in accordance with standard procedures (PSEP 1997) to estimate discharge. Alternatively, the independently measured value may be determined by routing the flow from a particular station to a container with a known volume (e.g. graduated cylinder, bucket, or jerrycan) and measuring the time required to fill this container.

Water level data - The independently measured value will be derived by measuring the water depth in the primary measuring device at a particular station using a staff gauge or ruler.

Precipitation depth - The independently measured value is the theoretical accuracy as specified by the manufacturer. The rain gauge's actual readings will be determined by measuring the volume of water required to initiate one tip of the associated bucket by adding incremental drops of water with a pipette.

Comparability - Comparability is the confidence with which one data set can be compared to another. Comparability can be related to accuracy and precision, as these quantities are measures of data reliability. Data are comparable if sample collection techniques, measurement procedures, analytical methods and reporting are equivalent for samples within a sample set.

To assure analytical comparability the laboratory will:

- Use National Bureau of Standards or USEPA - traceable standards
- Use standard methodologies
- Apply an appropriate level of quality control
- Participate in interlaboratory studies to document laboratory performance

As with representativeness, quantitative criteria for data comparability are difficult to establish, hence, a qualitative assessment of data comparability will be made of applicable data sets.

Completeness – An element of the data verification process. Completeness ensures that a sufficient amount of data and information (relative to the prescribed DQOs) are present. A Measurement Quality Objective (MQO), completeness is defined as the percentage of valid analytical results (results not qualified as R, rejected) obtained compared with the total number of analytical results required by the study scope of work. Analytical completeness is defined as the percentage of valid analytical results obtained compared with the total number of analyses requested. Completeness will be calculated as follows:

$$C(\%) = \frac{A}{I} x100\%$$

where:

% C	=	Percent completeness (field / laboratory)
A	=	Actual number of valid samples collected / analyses obtained
I	=	Intended number of samples / analyses requested

Compliance - An element of the data verification process. The extent that adherence to SOPs, QAPP, and/or contractual requirements were followed, achieved, and/or completed successfully, and that conditions under which the data were recorded also met the requirements. Compliance ensures that the data pass numerical quality control tests, including criteria on precision and accuracy, based on parameters or specified limits specified in relevant SOPs and or QAPP.

Composite samples – A composite sample is a mixed or combined sample that is formed by combining a series of individual and discrete samples of specific volumes at specified intervals. Although these intervals can be time-weighted or flow-weighted, the stormwater regulations require the collection of flow-weighted composite samples. This means that discrete aliquots, or samples, are collected and combined in proportion to flow rather than time. Composite samples characterize the quality of a stormwater discharge over a longer period of time, such as the duration of a storm event.

Consistency - An element of the data verification process. The extent to which data collection procedures were done in a similar manner across different sites (if applicable) and data reporting was done in a similar manner in multiple places. Consistency (also known as comparability) ensures that the reported values are the same when used throughout the study.

Correctness - An element of the data verification process. A mechanical, objective check that data collection plans and protocols have been followed and that basic operations and calculations were performed using properly documented and properly-applied algorithms. Correctness ensures that the reported values are based on properly documented algorithms.

Field Blanks - Field blanks are also commonly called field rinsate blanks, decontamination blanks and equipment blanks. A field blank evaluates the effectiveness of decontamination procedures when equipment is not dedicated to a site or disposed of after one use. If decontamination procedures are effective, there should be no contamination in the field blanks. Field blanks are not required if dedicated sampling equipment or disposable sampling equipment is used. A field blank consists of a sample of the reagent grade water supplied by the laboratory and used in the final rinse step of the equipment decontamination procedure. Process the field blank water through the equipment the same way you process any other final rinse water.

Field Replicates - A field replicate (duplicate) sample is collected to determine the variability of analytical results caused by the sampling equipment and procedures used.

Field replicates are samples collected simultaneously or sequentially from the same sampling location using identical sampling methods. The samples equally represent as nearly as possible the medium being sampled, and may provide information of the variance of chemicals at a sampling location and the consistency of sampling techniques.

Replicate samples will be collected at the time of sample collection. Replicate samples will be sent to the laboratory. The final number of replicate samples collected and submitted for analysis to each laboratory will equal or exceed 10 percent of the total number of primary samples for each analytical method.

Grab Sample - A grab sample is a discrete, individual sample collected within a short period of time (usually less than 15 minutes). Analysis of grab samples characterizes the quality of a storm water discharge at a given time of the discharge.

Interquartile Range (IQR) - The interquartile range (IQR) is the most commonly-used resistant measure of spread. It measures the range of the central 50 percent of the data, and is not influenced at all by the 25 percent on either end. The IQR is defined as the 75th percentile minus the 25th percentile.

The 75th, 50th (median) and 25th percentiles split the data into four equal-sized quarters. The 75th percentile (P.75), also called the upper quartile, is a value which exceeds no more than 75 percent of the data and is exceeded by no more than 25 percent of the data. The 25th percentile (P.25) or lower quartile is a value which exceeds no more than 25 percent of the data and is exceeded by no more than 75 percent.

Interim Minimum Level - The interim minimum level is calculated when a method specified ML does not exist. It is equal to 3.18 times the method specified MDL.

Laboratory Control Samples - Laboratory control samples (LCS) are well-characterized, laboratory-generated samples used to monitor the laboratory's day-to-day performance of routine analytical methods. Certain LCS are used to monitor the precision and accuracy of the analytical process, independent of matrix effects. Other LCS are used to identify any background interference or contamination of the analytical system which may lead to the reporting of elevated concentration levels or false positive measurements.

The results of the LCS are compared to well-defined laboratory acceptance criteria to determine whether the laboratory system is "in control." Controlling lab operations with LCS (as opposed to MS/MSD samples) offers the advantage of being able to differentiate low recoveries due to procedural errors from those due to matrix effects. One LCS should be analyzed for every set of 20 or fewer samples or with each sample preparation lot.

Percent recovery for laboratory controls will be calculated using the following equation:

$$\%R = \frac{M}{T} \times 100\%$$

where:

%R	=	percent recovery
M	=	measured value
T	=	true value.

Laboratory (or Matrix) Duplicate - A laboratory duplicate is a split of an environmental sample, which is prepared and analyzed in a manner identical to that of the original sample. The results are utilized to evaluate the precision of the laboratory analyses. Results are expressed in Relative Percent Difference (percent RPD) between analytical results for the split and the original sample.

If more than five but less than 20 samples are submitted, at least one laboratory duplicate should be analyzed. A general rule is one laboratory duplicate for every batch of up to 20 samples analyzed together.

Matrix Spike - A matrix spike (MS) is an environmental sample to which known concentrations of analytes have been added. The matrix spike is taken through the entire analytical procedure and the recovery of the analytes is calculated. Results are expressed as percent recovery of the known amount spiked. The matrix spike is used to evaluate the effect of the sample matrix on the accuracy of the analysis.

One matrix spike sample should be analyzed for every set of 20 or fewer samples or with each sample preparation lot. The spike solution is added to samples prior to digestion. The sample that is chosen for spiking should be the same sample used for laboratory duplicate analysis. The amount of spike added to the sample should be 2 to 5 times the expected sample concentration or the IDL, which ever is greater. Matrix spike recovery is calculated using the formula:

$$\%R = \frac{(S - U)}{C_{sa}} \times 100\%$$

where:

%R	=	percent recovery
S	=	measured concentration in spike sample
U	=	measured concentration in unspiked sample
C_{sa}	=	actual concentration of spike added.

Method Detection Limit (MDL) – The minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero as determined by a specific laboratory method (40 CFR 136).

Method or Preparation Blank - A method blank consists of analyte-free deionized water. The method blank is carried through each step of the analytical method. The method blank data will be used to detect any laboratory contamination during analysis.

A method blank is required for each batch of samples prepared for analysis, except in the case of volatile organic analyses, which should be analyze at least once every 12 hours.

Method Reporting Limit (MRL) – The concentration at which confidence in the reported value requires no qualifying remarks. The MRL should be 3-5 times the MDL. A standard is run at the MRL to verify acceptable data quality. The MRL may be affected by sample size, sample dilution, and matrix interference.

Minimum Level (ML) - the concentration at which the entire analytical system must give a recognizable signal and acceptable calibration point. The ML is the concentration in a sample that is equivalent to the concentration of the lowest calibration standard analyzed by a specific analytical procedure, assuming that all the method specified sample weights, volumes and processing steps have been followed.

Outlier - Outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected.

Precision Objectives - Precision is the degree of agreement between a set of replicate measurements. Precision will be measured as the relative percent difference (RPD) between duplicate analyses for matrix spike duplicates, laboratory duplicates, and field duplicates.

Precision RPD for matrix spike duplicates and laboratory duplicates will be within limits specified in the QAPP. Precision will be calculated as the relative percent

$$RPD_i(\%) = \frac{2|O_i - D_i|}{O_i + D_i} x100\%$$

difference (RPD) as follows:

where:

$\% RPD_i$	=	Relative percent difference for compound i
O_i	=	Value of compound i in original sample
D_i	=	Value of compound i in duplicate sample

The resultant %RPDs will be compared to the criteria specified in the QAPP and deviations from specified limits reported. If the objective criteria are not met, the laboratory will supply a justification of why the acceptability limits were exceeded and implement the appropriate actions. The percent RPDs will be reviewed during data validation, and deviations from the specified limits will be noted and the effect on reported data commented upon by the data reviewer.

Quality control objectives for field replicate precision have not been established by the USEPA. These analyses measure both field and lab precision; therefore, the results may also have more variability than lab duplicates which measure only lab performance. It is also expected that fish tissue replicate results will have a greater variance than water matrices due to the inherent variability in the fish.

Quartile skew coefficient, qs. A resistant measure of skewness. The difference in distances of the upper and lower quartiles from the median, divided by the IQR. A right-skewed distribution again has positive qs; a left-skewed distribution has negative qs. Similar to the IQR, qs uses the central 50 percent of the data.

Representativeness - Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter concentrations at a sampling point, or an environmental condition of a site. Representativeness is a function of sample site selection, sampling methods, and analytical techniques. The rationale for sample site selection and sampling methodology is provided in Section 8. Representativeness will be maintained by performing all sampling, sample handling, and analyses in compliance with the procedures described in this QAPP and the referenced analytical methods.

It is difficult to establish quantitative representativeness criteria. Representativeness of the analytical data may be determined by a comparison of the quality control data for the samples to established criteria, and by affirming that sampling and analytical methods conformed to established plans and methods.

Sample Type – Sample type refers to the king of sample that must be collected – either a grab or composite.

Sample Technique – Sample technique refers to the method by which a grab or composite sample is actually collected – either manually or by automatic sampler.

Standard Reference Material – Standard Reference Materials (SRM's) generall are considered the most useful QC samples for assessing thea ccuracy of a give analysis (i.e., the closeness of a measurement to he "true" value). SRM's can be used to assess accuracy because the have "certified" concentrations of the analystes of interest, as determined through replicate analyses by a reportable certifying agency using two independent measurement techniques for verification. In addition, the certifying agency may provide "non-certified" or "informational" values for other analytes of interest. Such values are determined using a single measurement technique, which may introduce unrecognized bias. Therefore, non-certified values must be used with caution in evaluating the performance of a laboratory using a method which differs from the one used by the certifying agency.

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Figures

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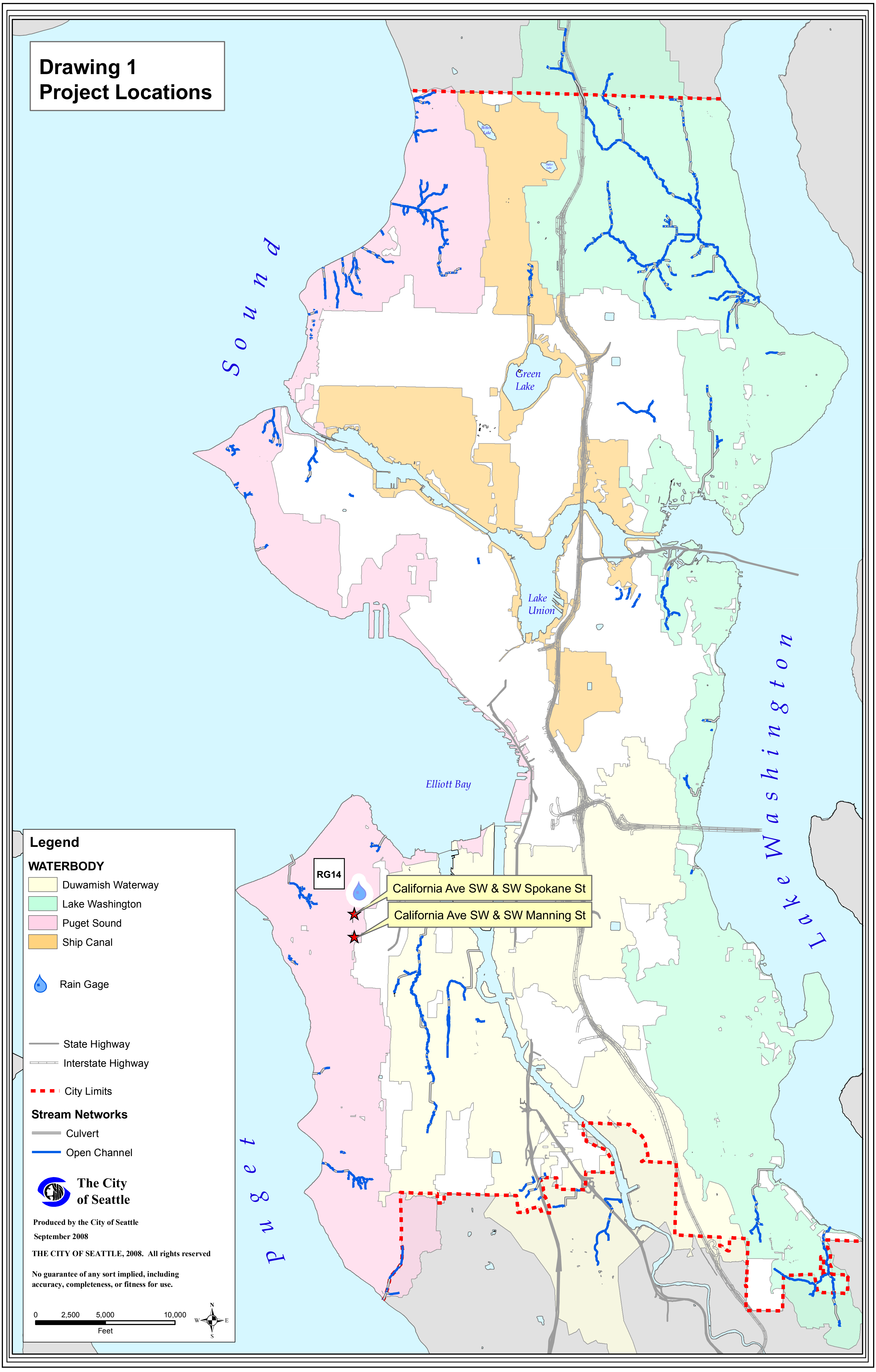


Drawing 1
Project Locations
Puget Sound
Green Lake
Lake Union
Elliott Bay
Lake Washington
RG14
California Ave SW & SW Spokane St
California Ave SW & SW Manning St
Legend
WATERBODY
Duwamish Waterway
Lake Washington
Puget Sound
Ship Canal
Rain Gage
State Highway
Interstate Highway
City Limits
Stream Networks
Culvert
Open Channel
The City of Seattle
Produced by the City of Seattle
September 2008
THE CITY OF SEATTLE, 2008. All rights reserved
No guarantee of any sort implied, including accuracy, completeness, or fitness for use.
0
2,500
5,000
10,000
Feet
N
E
S
W

BMP Effectiveness Monitoring

California Ave. SW & SW Spokane St.

The City of Seattle

Produced by the City of Seattle

January 2008

0 25 50 100
Feet

Legend

Catchbasin

Drainage Basin Boundary

Mainlines

Drainage Mainline

Sanitary Mainline

Combined Mainline

Metro Mainline

Streets

Residential

Arterial

State Highway

Interstate Highway

Streams

Culvert

Open Channel

Basin Size = 0.18 Acres

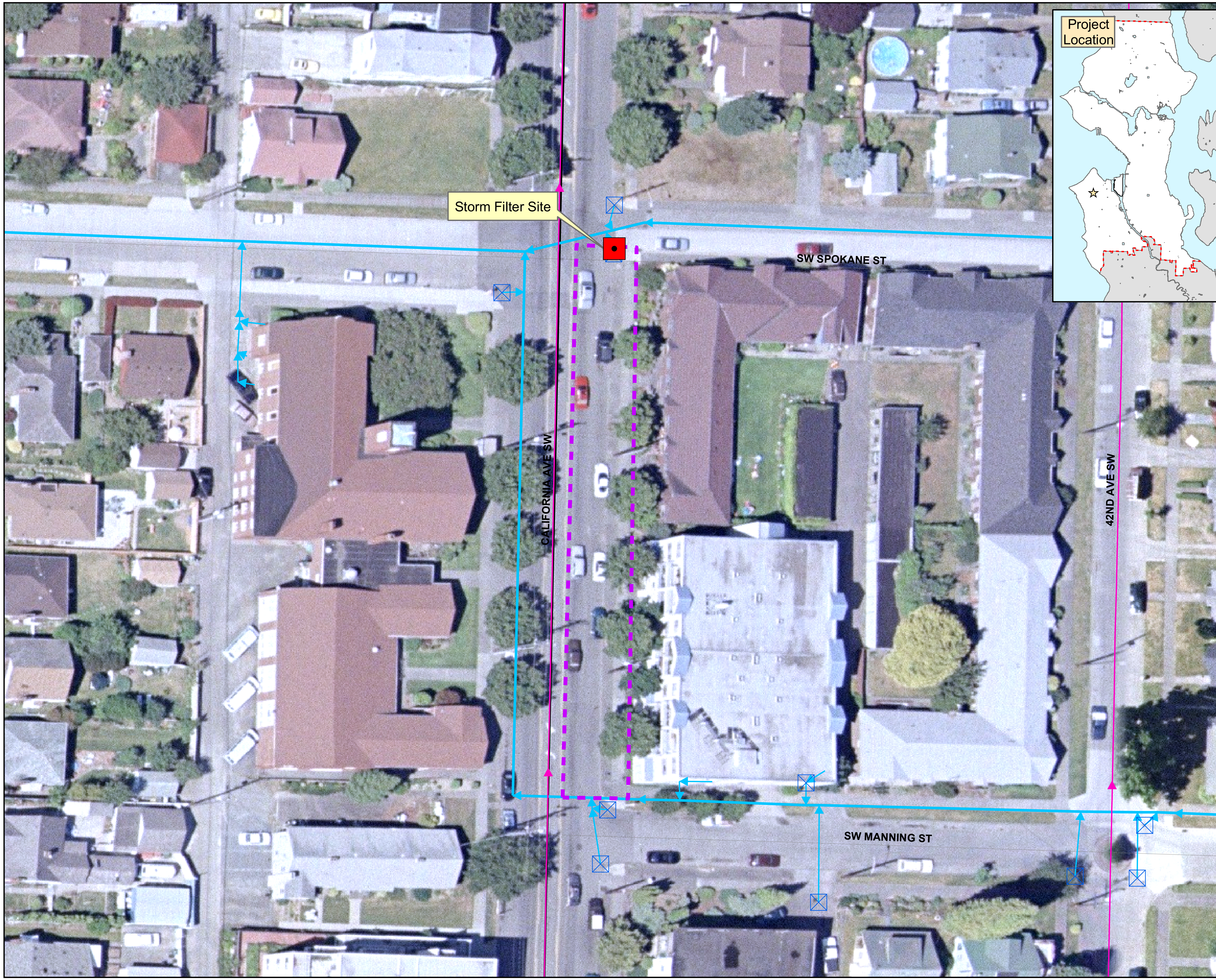


Figure 2.

BMP Effectiveness Monitoring

California Ave. SW & SW Manning St.

The City of Seattle

Produced by the City of Seattle

January 2008

0 25 50 100

Feet

Legend

Catchbasin

Drainage Basin Boundary

Mainlines

Drainage Mainline

Sanitary Mainline

Combined Mainline

Metro Mainline

Streets

Residential

Arterial

State Highway

Interstate Highway

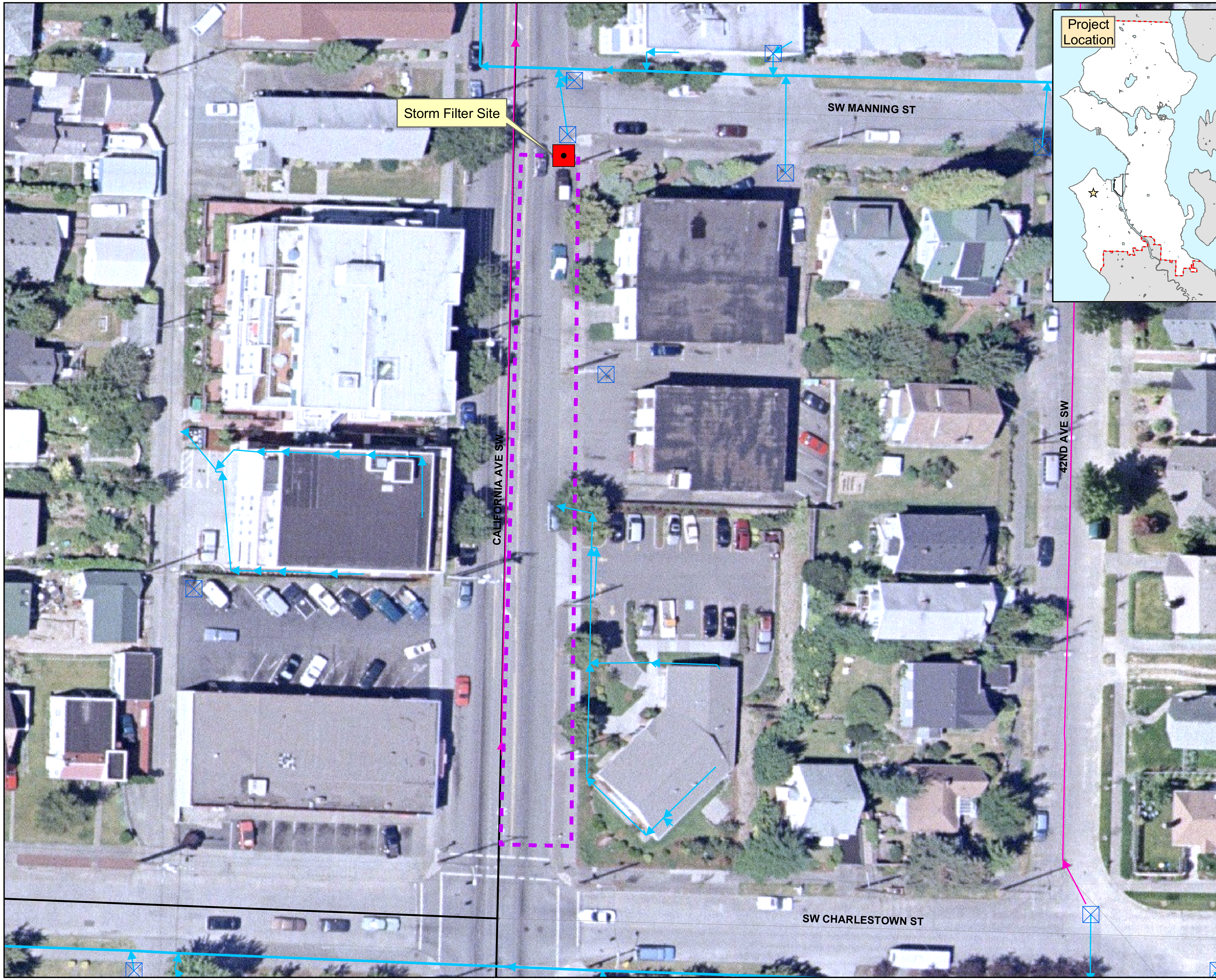
Streams

Culvert

Open Channel

Basin Size = 0.23 Acres

Figure 3.



02-04-08/rtb/HEC-R/06-03304-330/QAPP

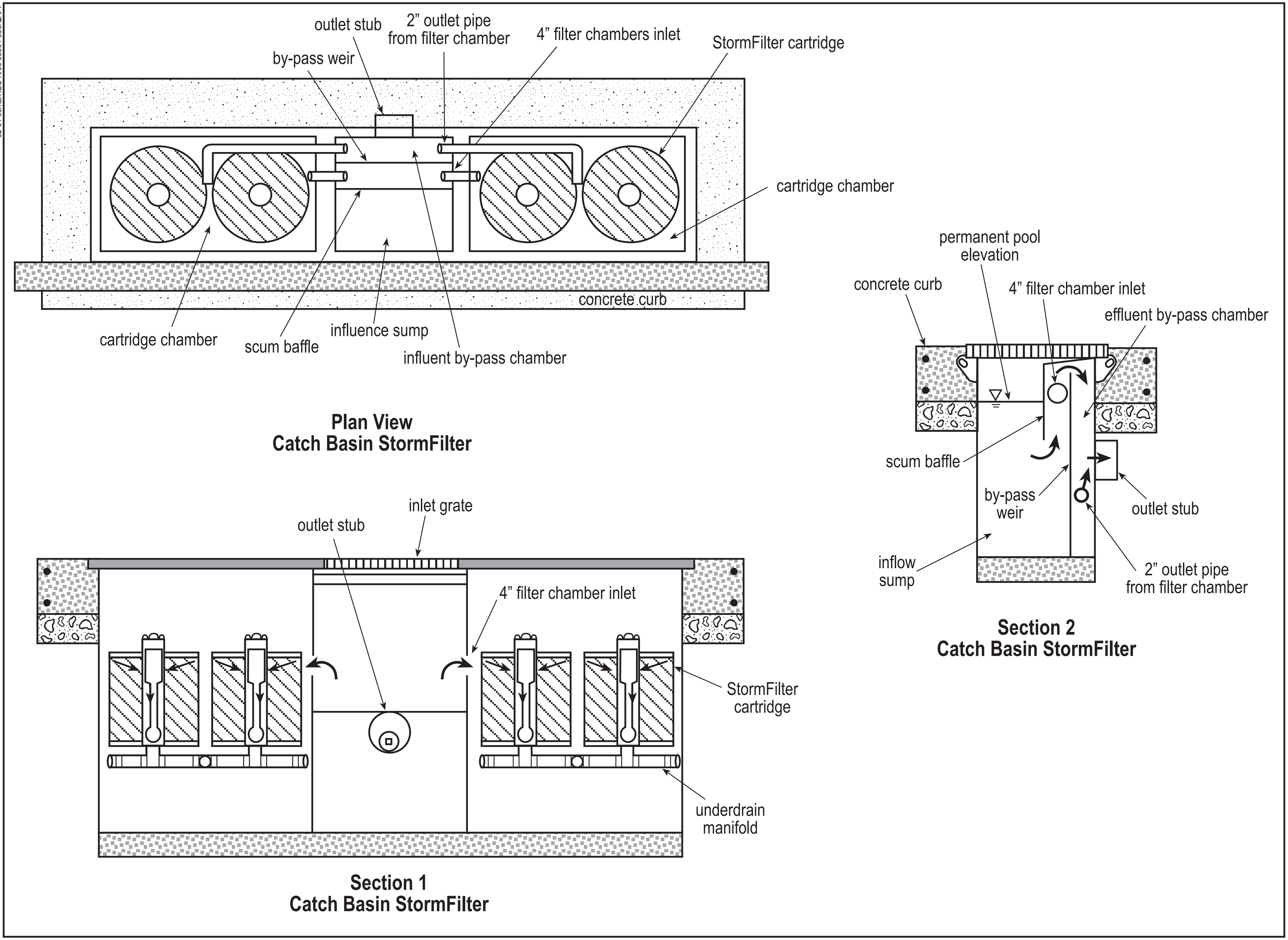


Figure 4. Design detail for catch basin StormFilters.

02-04-08/rtb/HEC-R/06-03304-330-005-001/QAPP

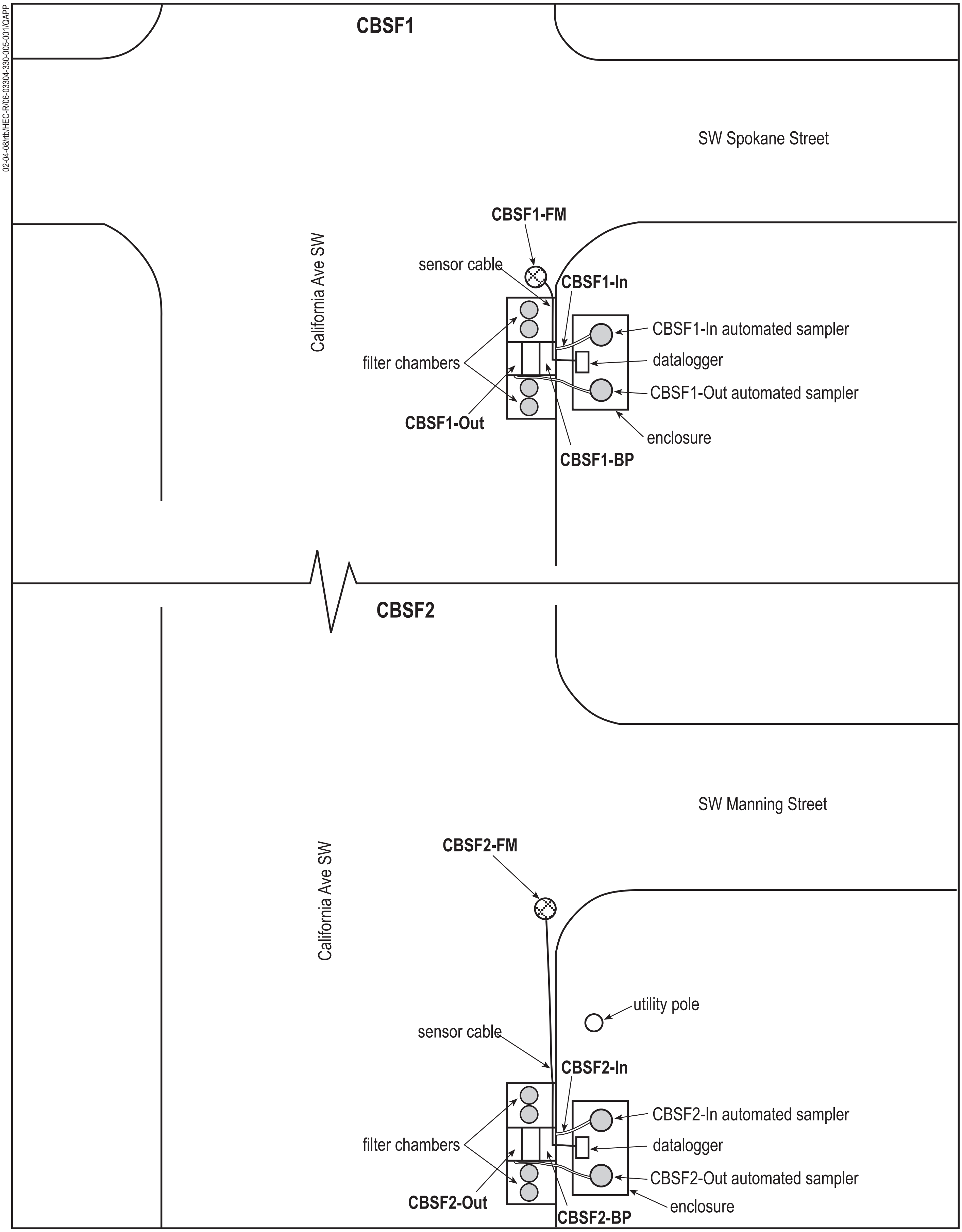


Figure 5. Schematic detail for monitoring stations in CBSF1 and CBSF2.

02-04-08/rtb/HEC-R/06-03304-330-005-001/QAPP

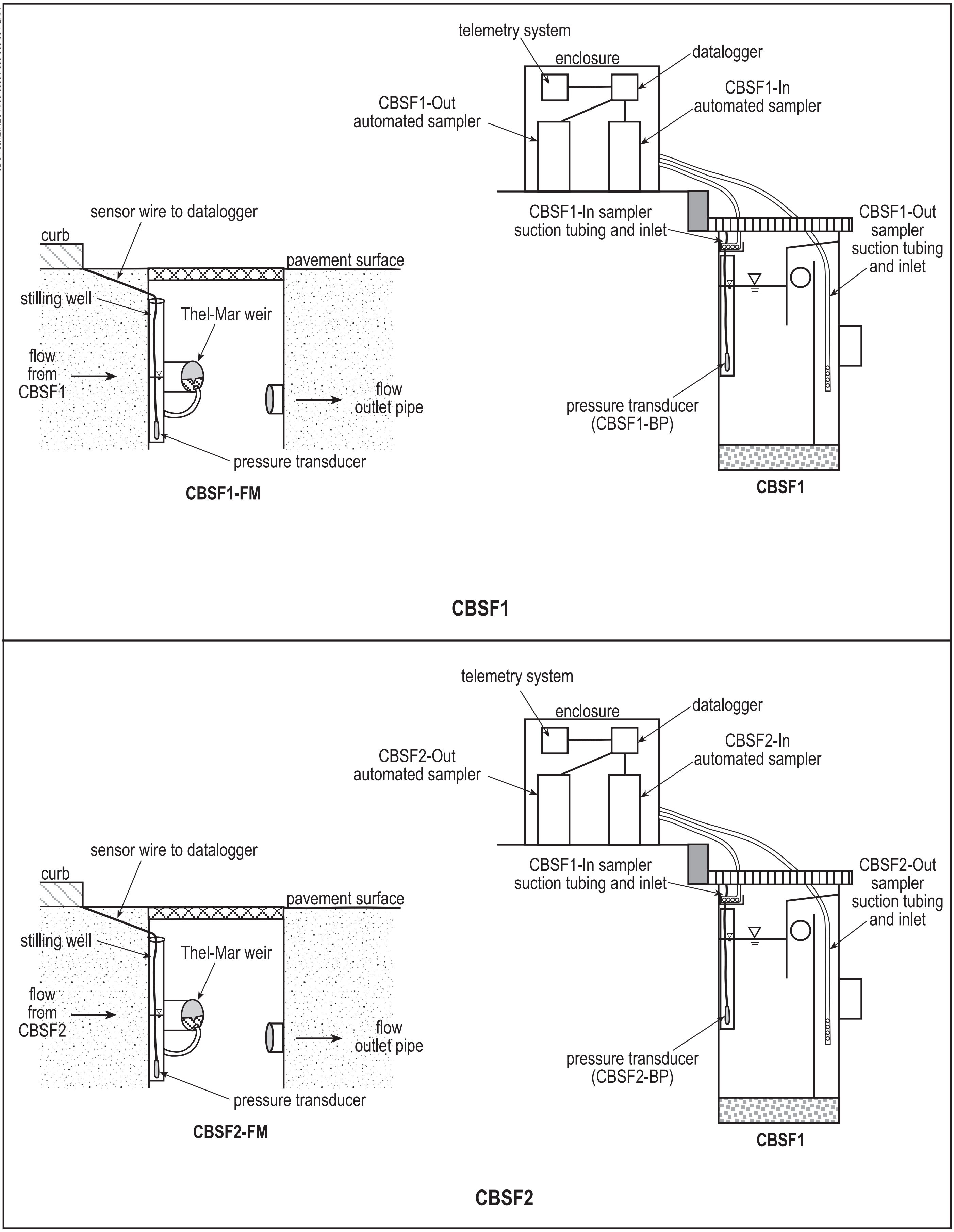


Figure 6. Schematic details for monitoring station in CBSF1 and CBSF2.

Appendix A

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FIELD LOG SHEET and FLOW DATA VALIDATION

Field Staff:___________________ Site:________________________ Weather:___________________

Maintenance Visit

Date/Time:

Station:		Station:		Station:	
Time Correct?		Time Correct?		Time Correct?	
Logger Level:		Logger Level:		Logger Level:	
Measured Level:		Measured Level:		Measured Level:	
System Volts:		System Volts:		System Volts:	
Rain Gauge:		Rain Gauge:		Rain Gauge:	
Dessicant:		Dessicant:		Dessicant:	
Notes:		Notes:		Notes:	

Pre-Storm Visit

Date/Time:

Time Correct?		Time Correct?		Time Correct?	
Logger Level:		Logger Level:		Logger Level:	
Measured Level:		Measured Level:		Measured Level:	
System Volts:		System Volts:		System Volts:	
Old Pacing:		Old Pacing:		Old Pacing:	
New Pacing:		New Pacing:		New Pacing:	
Program Started?		Program Started?		Program Started?	
Rain Gauge:		Rain Gauge:		Rain Gauge:	
Dessicant:		Dessicant:		Dessicant:	
Notes:		Notes:		Notes:	

Post-Storm Visit

Date/Time:

Date/Time End:		Date/Time End:		Date/Time End:	
# of Samples:		# of Samples:		# of Samples:	
Errors?		Errors?		Errors?	
Est. Sample Vol:		Est. Sample Vol:		Est. Sample Vol:	
Sent to Lab?		Sent to Lab?		Sent to Lab?	
Sample Dupped?		Sample Dupped?		Sample Dupped?	
System Volts:		System Volts:		System Volts:	
Dessicant:		Dessicant:		Dessicant:	
Notes:		Notes:		Notes:	

Flow Data Validation

Storm Depth:		Storm Depth:		Storm Depth:	
% Storm Sampled:		% Storm Sampled:		% Storm Sampled:	
Ant. Dry Time:		Ant. Dry Time:		Ant. Dry Time:	
Storm Volume:		Storm Volume:		Storm Volume:	

QAPP targets for Storm Depth = 0.15 in; % Storm Sampled = >75%; Antecedent Dry Time = 6 hr with <0.04 in

Additional Notes:

HERRERA ENVIRONMENTAL CONSULTANTS
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
(206) 441-9080
FAX (206) 441-9108

CHAIN OF CUSTODY RECORD

Page ___ of ___

PROJECT NAME: NPDESMONITREQ	PROJECT NUMBER: 06-03304-330	CLIENT: SPU
REPORT TO: Dylan Ahern - Herrera Environmental		COPY TO:
SAMPLED BY:		DELIVERY METHOD:
LABORATORY: Aquatic Research	REQUESTED COMPLETION DATE:	TOTAL # OF CONTAINERS:
LAB USE:		

ANALYSES REQUESTED

SAMPLE ID:	DATE:	TIME:	SAMPLE DESCRIPTION	# OF CONTAINERS:	Total Suspended Solids EPA 160.2	Particla Distribution Size TAPE method	Ph SM 4500-HB	Total Phosphorus EPA 365.1	Orthophosphorus EPA 365.2	Hardness SM2340B	Total and Dissolved Copper EPA220.2	Total and Dissolved Zinc EPA 200.7								

REMARKS:

RELINQUISHED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:	RECEIVED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:
RELINQUISHED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:	RECEIVED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:

HERRERA ENVIRONMENTAL CONSULTANTS

2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
(206) 441-9080
FAX (206) 441-9108

CHAIN OF CUSTODY RECORD

PROJECT NAME: NPDESMONITREQ	PROJECT NUMBER: 06-03304-330	CLIENT: SPU
REPORT TO: Dylan Ahern - Herrera Environmental		COPY TO:
SAMPLED BY:		DELIVERY METHOD:
LABORATORY: Analytical Resources, Inc.	REQUESTED COMPLETION DATE:	TOTAL # OF CONTAINERS:
LAB USE:		

ANALYSES REQUESTED

SAMPLE ID:	DATE:	TIME:	SAMPLE DESCRIPTION	# OF CONTAINERS:	Grain Size ASTM D422	Bulk Density ASTM D2937	Percent Total Solids SM 2540B	Total Volatile Solids SM 2540 E	Total Phosphorus EPA 365.2	Total Metals (Cd, Cu, Pb, Zn) EPA 6010	Petroleum Hydrocarbons NWTPH-Dx									

REMARKS:

RELINQUISHED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:	RECEIVED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:
RELINQUISHED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:	RECEIVED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:

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Appendix B

Specifications

Flo-Tote 3 Sensor Model 3000

Material

Standard: Polyurethane exposed to flow.

Dimensions: 5 $^{3}/_{16}$" L x 1 ¾ " W x 1 $^{1}/_{8}$" H
(13.1 cm x 4.4 cm x 2.8 cm)

Weight: 2.5 lbs. (1.1 kg) with 30 Ft. Cable

Operating Temperature Range: 32° to 113° F (0º to 45º C)

Storage Temperature: -4º to 125º F (-20º to 51º C)

Velocity Measurement

Method: Electromagnetic (Faraday's Law)

Range: -5 to +20 ft/s (-1.5 to +6.1 m/s)

Accuracy: ±2% of reading, ± 0.05 zero stability at 0 to +10 ft/s
(0 to 3.04 m/s)

Zero Stability: ±0.05 ft/s (±15.2 mm/s)

Resolution: 0.01 ft/s (3.05 mm/s)

Level Measurement

Method: Submerged pressure transducer

Range: Standard 0.4 to 138 inches. (10 mm to 3.5 m)
Contact factory for extended ranges.

Accuracy: ± 1% reading, ± 0.03, zero stability for 0 to 10 ft/sec.
(0 to 3.04 m/s)
Includes non-linearity, hysteresis and velocity effects.

Zero Stability: ± 0.03 ft. (.009 m)

Resolution: 0.1 inch (2.5 mm)

Over Range Protection: 2 X range

Flow Measurement

Method: Conversion of water level and pipe size to fluid area.
Conversion of local velocity reading to mean velocity. Multiplication of fluid area by mean velocity to equal flow rate.

Conversion Accuracy: ±5.0% of reading. Assumes pipe is 10 to 90% full and with a level greater than 2 inches (5.08 cm)

Temperature Measurement:

Method: 1 wire digital thermometer

Range: 14º to 185º F (-10º to 85º C)

Accuracy: ±3.5º F/C

Sensor Cable

Material: Polyurethane jacketed

Standard Length: 30 feet (9.1 m)

Optional Lengths: 60, 100 feet (18.2 m, 30.4 m) or length as needed

Contact MMI for Sensor Installation Hardware Ordering Information (sold separately).

Contact MMI for Flo-Logger/Flo-Station Options/Accessories List

Flo-Logger Model 1000-1 (Portable Installations)

Data Storage

64K (16K cycles of velocity/level data)

Local Terminal

RS232C at 19.2K baud

Power Requirements

12 VDC (Two six volt lantern batteries are supplied standard.)

Battery Life

16 weeks typical at a sample interval of 15 minutes using recommended batteries.

Housing

Sealed watertight (IP68) PVC enclosure

Length: 13.85" (35.179 cm)

Diameter: 7.75" (19.685 cm)

Weight: 7.5 lbs. (3.4 kg) (including batteries)

Temperature

Operating Temperature Range: 14° F to 125° F (-10° C to 51° C)

Storage Temperature Range: -4° F to 125° F (-20° C to 51° C)

Sensor/Logger Disconnect

Both the sensor and the logger have waterproof (IP68) connectors for easy separation from the interconnecting cable.

Flo-Station Model 1000-2 (Permanent Installations)

Data Storage

64K (16K cycles of velocity/level data)

Local Terminal

RS232C at 19.2K baud

4-20 mA Outputs

Four 4-20 mA outputs standard. (4) programmable, isolated outputs capable of driving 650 ohm each.

Contact Closure (Optional)

One form C dry contact closure

Power Requirements

+12 VDC @ 220 mA with all four 4-20mA outputs @ 20mA

Housing

Material: Polystyrene (NEMA 4X, IP66/67-7)

Dimensions: 9" W x 7" H x 4" D (22.8 cm x 17.7 cm x 10.1 cm)

Weight: 7.5 lbs. (3.4 kg)

Temperature

Operating Temperature Range: 14° F to 122° F (-10° C to 50° C)

Storage Temperature Range: -4° F to 122° F (-20° C to 50° C)

Software – Flo-Tote 3 Flowmeter System

Set-Up/Data Retrieval/Reporting

Flo-Ware/Flo-Ware FX for Windows software (sold separately) is the user on-site set-up, data management and report generation software for the Flo-Tote 3 Flowmeter System. It is compatible with computers (desktop/portable/Pocket PC) utilizing Windows 95/98/2000/Me/NT/XP and Pocket PC 2002. Flo-Ware for Windows software can retrieve data from both Flo-Tote 3 and Flo-Dar Model 464/460 Flowmeters.

CR1000 Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years. We recommend that the system configuration and critical specifications are confirmed with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE
10 ms to 30 min. @ 10 ms increments

ANALOG INPUTS
8 differential (DF) or 16 single-ended (SE) individually configured. Channel expansion provided by AM16/32 and AM25T multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. **Resolution of DF measurements with input reversal is half the Basic Res.**

	Input Referred Noise Voltage	
Input Range (mV)[1]	*DF Res (μV)*[2]	*Basic Res (μV)*
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1]Range overhead of ~9% exists on all ranges to guarantee that full-scale values will not cause over-range.

[2]Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset), -55° to 85°C

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range; digital resolution dominates for higher ranges.

250 μs Integration:	0.34 μV RMS
50/60 Hz Integration:	0.19 μV RMS

MINIMUM TIME BETWEEN VOLTAGE MEASUREMENTS: Includes the measurement time and conversion to engineering units. For voltage measurements, the CR1000 integrates the input signal for 0.25 ms or a full 16.66 ms or 20 ms line cycle for 50/60 Hz noise rejection. DF measurements with input reversal incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors and therefore take twice as long.

250 μs Analog Integration:	~1 ms SE
1/60 Hz Analog Integration:	~20 ms SE
1/50 Hz Analog Integration:	~25 ms SE

COMMON MODE RANGE: ±5 V

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

ANALOG OUTPUTS
3 switched voltage, active only during measurement, one at a time.

RANGE AND RESOLUTION: Voltage outputs programmable between ±2.5 V with 0.67 mV resolution.

ACCURACY: ±(0.06% of setting + 0.8 mV), 0° to 40°C
±(0.12% of setting + 0.8 mV), -25° to 50°C
±(0.18% of setting + 0.8 mV), -55° to 85°C (-XT only)

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS
MEASUREMENT TYPES: The CR1000 provides ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation using any of the 3 switched voltage excitations eliminates dc errors.

RATIO ACCURACY[3]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error.

±(0.04% of voltage reading + offset)/V_x

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

Offset values are reduced by a factor of 2 when excitation reversal is used.

PERIOD AVERAGING MEASUREMENTS
The average period for a single cycle is determined by measuring the average duration of a specified number of cycles. The period resolution is 192 ns divided by the specified number of cycles to be measured; the period accuracy is ±(0.01% of reading + resolution). Any of the 16 SE analog inputs can be used for period averaging. Signal limiting are typically required for the SE analog channel.

INPUT FREQUENCY RANGE:

Input Range	*Signal (peak to peak)*[4] *Min*	*Max*	*Min. Pulse W.*	*Max*[5] *Freq.*
±2500 mV	500 mV	10 V	2.5 μs	200 kHz
±250 mV	10 mV	2 V	10 μs	50 kHz
±25 mV	5 mV	2 V	62 μs	8 kHz
±2.5 mV	2 mV	2 V	100 μs	5 kHz

[4]The signal is centered at the datalogger ground.

[5]The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

PULSE COUNTERS
Two 24-bit inputs selectable for switch closure, high-frequency pulse, or low-level AC.

MAXIMUM COUNTS PER SCAN: 16.7×10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH-FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 μs time constant.

LOW-LEVEL AC MODE: Internal AC coupling removes AC offsets up to ±0.5 V.

Input Hysteresis: 16 mV @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	*Range (Hz)*
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS
8 ports software selectable, as binary inputs or control outputs. C1-C8 also provide edge timing, subroutine interrupts/wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UART), SDI-12 communications, and SDM communications.

HIGH-FREQUENCY PULSE MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 5.3 V; low -0.3 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE: 100 kohms

SWITCHED 12 V
One independent 12 V unregulated sources switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

SDI-12 INTERFACE SUPPORT
Control ports 1, 3, 5, and 7 may be configured for SDI-12 asynchronous communications. Up to ten SDI-12 sensors are supported per port. It meets SDI-12 Standard version 1.3 for datalogger mode.

CE COMPLIANCE
STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

CPU AND INTERFACE
PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and data storage.

SERIAL INTERFACES: CS I/O port is used to interface with Campbell Scientific peripherals; RS-232 port is for computer or non-CSI modem connection.

PARALLEL INTERFACE: 40-pin interface for attaching data storage or communication peripherals such as the CFM100 module

BAUD RATES: Selectable from 300 bps to 115.2 kbps. ASCII protocol is one start bit, one stop bit, eight data bits, and no parity.

CLOCK ACCURACY: ±3 min. per year

SYSTEM POWER REQUIREMENTS
VOLTAGE: 9.6 to 16 Vdc (reverse polarity protected)

TYPICAL CURRENT DRAIN:
Sleep Mode: ~0.6 mA
1 Hz Scan (8 diff. meas., 60 Hz rej., 2 pulse meas.)
w/RS-232 communication: 19 mA
w/o RS-232 communication: 4.2 mA
1 Hz Scan (8 diff. meas., 250 μs integ., 2 pulse meas.)
w/RS-232 communication: 16.7 mA
w/o RS-232 communication: 1 mA
100 Hz Scan (4 diff. meas., 250 μs integ.)
w/RS-232 communication: 27.6 mA
w/o RS-232 communication: 16.2 mA

CR1000KD CURRENT DRAIN:
Inactive: negligible
Active w/o backlight: 7 mA
Active w/backlight: 100 mA

EXTERNAL BATTERIES: 12 Vdc nominal

PHYSICAL SPECIFICATIONS
MEASUREMENT & CONTROL MODULE SIZE: 8.5" x 3.9" x 0.85" (21.6 x 9.9 x 2.2 cm)

CR1000WP WIRING PANEL SIZE: 9.4" x 4" x 2.4" (23.9 x 10.2 x 6.1 cm); additional clearance required for serial cable and sensor leads.

WEIGHT: 2.1 lbs (1 kg)

WARRANTY
Three years against defects in materials and workmanship.

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formerly knaackbox.com

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KNAACK JOBMASTER® Storage Chest Model 4830

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click image to enlarge

Knaack Jobmaster Chest Model 4830

$418.40

Catalog Number: KN4830
Model 4830 Knaack® JOBMASTER® Chest, 25.25 Cu Ft.

Security and durability to go. JOBMASTER® Chests are tool storage solutions that are as easy to handle as they are tough. They're compact enough to be lifted and moved around the jobsite or into a work vehicle with minimal effort.

FEATURES:

- WATCHMAN® IV Lock System with 3-point latching and recessed lock housing for the ultimate protection against pry-ins. One-time lock installation means no downtime replacing locks.
- Power Pass™ electrical pass-through grommet for easy weatherproof power cord access
- Reinforced lock housing providing unbeatable strength
- Heavy-duty hinges staked and welded to stand up to any amount of prying
- Recessed handles for positive gripping even with a gloved hand
- Baked-on enamel finish for weather resistance and durability
- Caster-ready 12-gauge steel skids to accommodate optional casters
- Heavy-duty 16-gauge steel construction with fully arc-welded seams

Weight: 194 lbs

Select Qty. 1 Check Stock

Ship to Myself

ADD TO CART

Specifications | Accessories

Capacity: 25.25 Cu Ft
Closed Height: 34.25"
Width: 48"
Depth: 30"
Opened Lid Height: 29" box only; 61.25" box plus opened lid

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VOLUMETRIC WEIRS

For measuring flows in Manholes and Open End Pipes

WEIR SET
(refer to back page for details)

15" WEIR WITH 18" ADAPTER

WEIR WITH BUBBLER TUBE

The most practical, economical instrument for testing new sewer lines - night flow studies of existing lines – free flow from open end pipe.

A VOLUMETRIC calibrated weir is a portable flow measuring device that is used to determine infiltration in newly installed sewer lines, or measure substantial flows in existing lines.

THE THEL-MAR VOLUMETRIC weir is basically a compound weir that incorporates the advantage of a 90° V-notch for measuring small infiltration flow where accuracy is of prime importance. The V-notch section measures from 57 gallons to 3700 gallons per 24 hours, which is the range of normal Acceptance Test Requirements. The rectangular section of the weir is capable of measuring in gallons per day up to 35% of pipe capacity.

A BUBBLE LEVEL is mounted at the top of the weir's face plate for easy visibility. Thel-Mar weirs are calibrated in U.S. GALLONS PER 24 HOURS (METRIC WEIRS CUBIC METERS PER HOUR) in large, easy to read type. Calibration lines are in 2 millimeter increments.

DISCHARGE CALIBRATIONS for the Volumetric Weir were accurately determined in a hydraulic laboratory where manhole conditions were duplicated. Therefore, there are no induced errors by insufficient drop of the nappe or by contractions, velocity of approach, submergency, or drawdown.

RUGGED CONSTRUCTION and noncorroding materials make the Thel-Mar weir extremely reliable. There are no loose parts that require assembly. Installation is quick and positive and the weir requires a minimum of care.

A COMPOUND WEIR offers minimum restriction to flow and is relatively free from becoming clogged by debris from sewage. Thel-Mar weirs can be installed for extended periods of time without accumulation of sediment.

ERRORS IN EXCESS OF 100% exist in other calibrated V-notch weirs. Unlike the Thel-Mar weir these were calibrated by the cone formula.

EASY TO READ FLOW RATE Simply check water level at the face plate. The figure above the line matching the water level gives you the rate of flow in GALLONS PER 24 HOURS (METRIC WEIRS-CUBIC METERS PER HOUR).

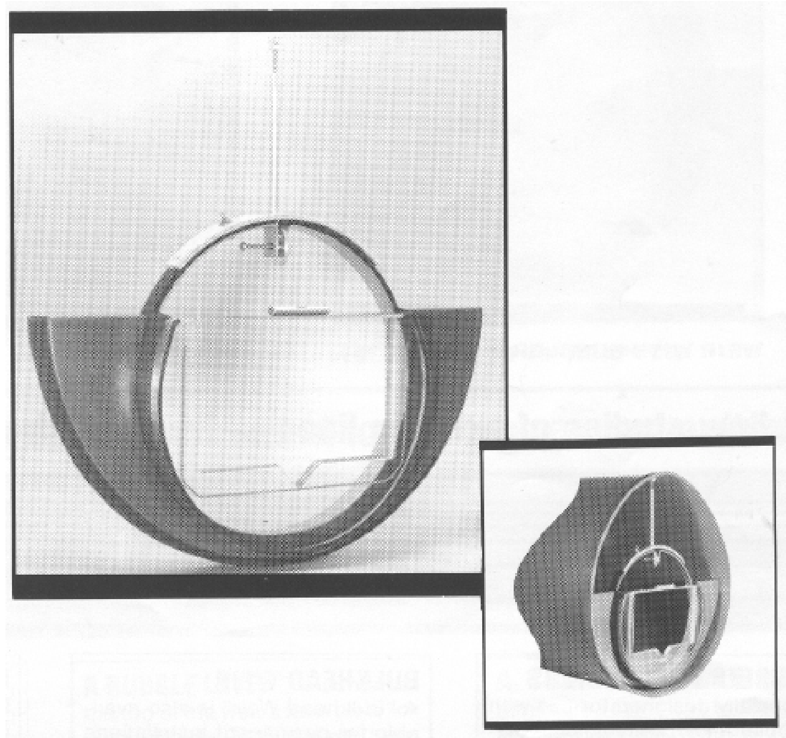
BUBBLER FLOW METERS Especially designed for use with Bubbler Flow Meters, all Volumetric Weirs are now available with an attached "Bubbler Tube". These weirs are manufactured with a 1/8 inch O.D. stainless steel tube attached to the right side of the adjustable ring. The bubbler tube protrudes forward approximately two inches from near the top of the ring for easy connection to a line. It runs from there down the inside of the ring to approximately 1 3/8-inch behind and below the V-notch. This bubbler tube does not in any way affect the function of the Volumetric Weir.

INSTALLATION INSTRUCTIONS Prior to installation, the interior edge of the incoming pipe should be cleared of sediment and foriegn matter to assure seal of the gasket.

Turn thumb-wheel to extreme right. Place hand through weir opening, wiht thumb and index finger compress spring. Insert weir into incoming pipe about 1", and release tension from spring. Secure by turning thumb-wheel to left and finger tighten.

Allow sufficient time for water to back up and behind the weir and establish a uniform flow; five to ten minutes for existing flow to an hour for accurate infiltration readings.

15” WEIR WITH ADAPTOR INSTALLED IN 24” PIPE



Individual Volumetric Weirs are available for 6", 8", 10", 12", 14", 15" and 16" pipe. The 14" weir uses a 12" face plate. Adaptors for 18", 21", 24", 27", 30", 36", 42" and 48" pipe are used in conjunction with the 15" weir.

Volumetric Weirs are also available in a set. Set A consists of 6", 8", 10’, 12" and 15" weirs with an 18” adaptor and carrying case with handle and hasp. It measures 191/2"W x 191/2"D x 71/2"H. Set B is similar and designed to be used with Bubbler Flow Meters.

Adaptors are available individually or in a set. Set C consists of 21" through 48" adaptors. No carrying case included.

WEIR CAPACITIES AND HEAD

CAPACITIES*			HEAD**
6"	57 to 3700 GPD within V-notch,	rectangular to 46,000 GPD	2.8437
8"	57 to 3700 GPD within V-notch,	rectangular to 124,000 GPD	4.0000
10"	57 to 3700 GPD within V-notch,	rectangular to 234,000 GPD	5.1250
12"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
14"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
15"	57 to 3700 GPD within V-notch,	rectangular to 610,000 GPD	7.3125
16"	57 to 3700 GPD within V-notch,	rectangular to 610,000 GPD	7.3125
Bulkhead Weir	57 to 3700 GPD within V-notch,	rectangular to 610,000 GPD	7.3125

* Calibration lines are in 2 millimeter increments.
** In inches from top of rectangular opening to bottom of V-notch.

Parson Environmental Products, Inc.   *   P.O. Box 4474   *   Reading, PA 19606
Toll Free: (800) 356-9023   *   Voice: (610) 582-6060   *   Fax: (610) 582-6064
WEB SITE: www.parsonenvironmental.com

Ps-9 SERIES

PS9805 SUBMERSIBLE PRESSURE TRANSDUCER (mV output)

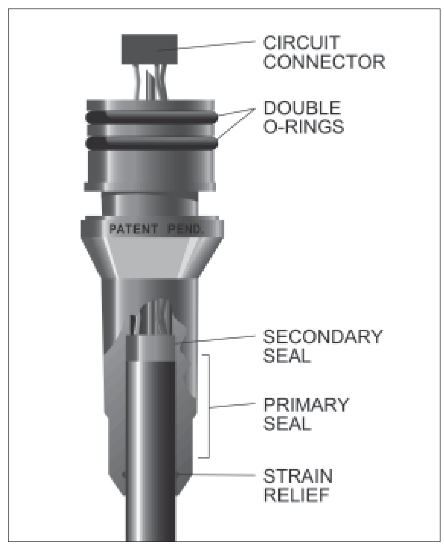
FEATURES

- Low power, passive operation
- Small diameter
- Double-sealing
- ***Pressure and temperature outputs***
- 316 stainless steel, Viton® and Teflon® construction
- Polyethylene, polyurethane and FEP Teflon® cable options
- Competitive pricing, immediate availability

DESCRIPTION

INW's improved PS9805 submersible pressure transducer is designed to provide level and temperature measurement in most types of liquid environments. The PS9805 features the latest in silicon, micro-machined, piezoresistive, strain gauge technology, and temperature measurement technology. This sensor is specifically designed to be compatible with Campbell Scientific measurement and control equipment.

The cable harness design reduces the probability of leakage and protects the cable jacket from damage by providing double-sealing; 316 stainless steel, Viton® and Teflon® construction increases corrosion resistance. The transducer's end cone is interchangeable with a 1/4" NPT inlet, which expands application possibilities by permitting easy hook-up and field calibration. The modular-designed PS9805 may be easily factory serviced and repaired.



PS9805 cable harness design showing double seal and strain relief.

OPERATION

The PS9805 pressure/temperature transducer requires a minimum of one differential channel and one single ended channel to measure pressure and one single ended channel to measure temperature. Data is processed within the datalogger and the results are converted to the desired units of pressure and temperature. If desired, an optional enhanced thermal calibration can also be performed to more accurately compensate for temperature changes.

APPLICATIONS

- Ground water monitoring
- Tank and tidal levels
- Pump control
- Flow monitoring
- Stream stage
- Aquifer testing

INDUSTRIES

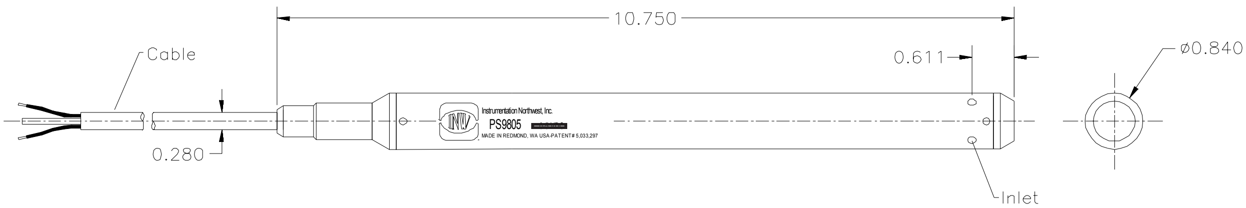
- Environmental remediation
- Irrigation
- Natural resource management
- Mining
- Water Supply
- Wastewater treatment

INW®
Instrumentation Northwest, Inc.
1-800-776-9355
http://www.inwusa.com

Ps-9 SERIES

PS9805 SUBMERSIBLE PRESSURE TRANSDUCER (mV output)

DIMENSIONS AND SPECIFICATIONS



HOW TO ORDER

- Choose the transducer with the required pressure range.
- Determine cable type and specify length.
- Pick options such as military connectors or wire seals
- Contact INW for a full list of accessories.

PS9805 SUBMERSIBLE PRESSURE TRANSDUCER RANGES			
3C346	1 PSIG	3C302	30 PSIG
3C347	2.5 PSIG	3C303	50 PSIG
3C300	5 PSIG	3C304	100 PSIG
3C301	15 PSIG		
S9805 CABLE OPTIONS			
6E540	Polyurethane Jacketed Cable		
6E542	Polyethylene Jacketed Cable		
6E543	FEP Teflon Jacketed Cable		
PS9805 OPTIONS (factory performed or installed)			
3C282	Enhanced Temperature Calibration	3D106	M-10 Mil-Spec Connectors
ACCESSORIES			
6E410	1/4” NPT Adapter Kit	6E517	Transducer Cable Strain Relief Kit

Information in this document is subject to change without notice.

MECHANICAL

TRANSDUCER

Body Material	316 stainless steel
Wire Seal Materials	Viton® and Teflon®
Desiccant	High- and standard capacity available
Terminating Connector	Available
Weight	.75 pounds

CABLE

Conductor Type	9-conductor
Vent Tube	Nylon
OD	0.28” maximum
Break Strength	138 pounds
Maximum Length	2000 feet
Weight	4 lbs. per 100 feet

ELECTRICAL

Linearity/	±0.1% FSO (typical)
Repeatability/ Hysteresis*	±0.1% FSO (typical)
Typical Output Voltage Sensitivity at 20° C	15-16 mV/V
Maximum Zero Offset at 20° C	3 mV
Common Mode Voltage	Vi/2
Bridge Resistance at 20° C	4 kohm (typical)
Standard Temperature Error	±2.0% FSO 0-40 degrees
Enhanced Temperature Error if optional calibration is ordered	±.0.2% FSO 0-40 degrees
Typical Excitation Voltage	0.8 volts
Compensated Temperature Range	0-40° C
Operating Temperature Range	-5° to 70° C
Over Range Protection	2x Full Scale Range

*Best fit straight line

Instrumentation Northwest, Inc.

INW®

Sales and Service Locations
8902 122nd Ave NE, Kirkland • Washington 98033 USA
(425) 822-4434 • (425) 822-8384 FAX • info@inwusa.com
4620 Northgate Boulevard, Suite 170 • Sacramento, California 95834
(916) 922-2900 • (916) 648-7766 FAX • inwsw@inwusa.com

1-800-776-9355
http://www.inwusa.com

CR800-series Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years. We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE

10 ms to 30 min. @ 10 ms increments

ANALOG INPUTS

3 differential (DF) or 6 single-ended (SE) individually configured. Channel expansion provided by AM16/32 and AM25T multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. **Resolution of DF measurements with input reversal is half the Basic Res.**

Input Range (mV)[1]	Input Referred Noise Voltage DF Res (μV)[2]	Basic Res (μV)
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1]Range overhead of ~9% exists on all ranges to guarantee that full-scale values will not cause over-range.

[2]Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset), -55° to 85°C

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range; digital resolution dominates for higher ranges.

250 μs Integration: 0.34 μV RMS
50/60 Hz Integration: 0.19 μV RMS

MINIMUM TIME BETWEEN VOLTAGE MEASUREMENTS: Includes the measurement time and conversion to engineering units. For voltage measurements, the CR800-series integrates the input signal for 0.25 ms or a full 16.66 ms or 20 ms line cycle for 50/60 Hz noise rejection. DF measurements with input reversal incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors and therefore take twice as long.

250 μs Analog Integration: ~1 ms SE
1/60 Hz Analog Integration: ~20 ms SE
1/50 Hz Analog Integration: ~25 ms SE

COMMON MODE RANGE: ±5 V

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

ANALOG OUTPUTS

2 switched voltage, active only during measurement, one at a time.

RANGE AND RESOLUTION: Voltage outputs programmable between ±2.5 V with 0.67 mV resolution.

ACCURACY: ±(0.06% of setting + 0.8 mV), 0° to 40°C
±(0.12% of setting + 0.8 mV), -25° to 50°C
±(0.18% of setting + 0.8 mV), -55° to 85°C (-XT only)

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR800-series provides ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation using any of the 3 switched voltage excitations eliminates dc errors.

RATIO ACCURACY[3]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error.

±(0.04% of voltage reading + offset)/V_x

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

Offset values are reduced by a factor of 2 when excitation reversal is used.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the average duration of a specified number of cycles. The period resolution is 192 ns divided by the specified number of cycles to be measured; the period accuracy is ±(0.01% of reading + resolution). Any of the 6 SE analog inputs can be used for period averaging. Signal limiting are typically required for the SE analog channel.

INPUT FREQUENCY RANGE:

Input Range	Signal (peak to peak)[4] Min	Max	Min. Pulse W.	Max[5] Freq.
±2500 mV	500 mV	10 V	2.5 μs	200 kHz
±250 mV	10 mV	2 V	10 μs	50 kHz
±25 mV	5 mV	2 V	62 μs	8 kHz
±2.5 mV	2 mV	2 V	100 μs	5 kHz

[4]The signal is centered at the datalogger ground.

[5]The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

PULSE COUNTERS

Two 24-bit inputs selectable for switch closure, high frequency pulse, or low-level ac.

MAXIMUM COUNTS PER SCAN: 16.7×10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 μs time constant.

LOW LEVEL AC MODE: Internal ac coupling removes dc offsets up to ±0.5 V.

Input Hysteresis: 16 mV @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	Range (Hz)
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS

4 ports software selectable, as binary inputs or control outputs. They also provide edge timing, subroutine interrupts/wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UART), SDI-12 communications, and SDM communications.

HIGH FREQUENCY MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 5.3 V; low -0.3 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE: 100 kohms

SWITCHED 12 V

One independent 12 V unregulated sources switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

SDI-12 INTERFACE SUPPORT

Control ports 1 and 3 may be configured for SDI-12 asynchronous communications. Up to ten SDI-12 sensors are supported per port. It meets SDI-12 Standard version 1.3 for datalogger mode.

CE COMPLIANCE

STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

CPU AND INTERFACE

PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and data storage

SERIAL INTERFACES: CS I/O port is used to interface with Campbell Scientific peripherals; RS-232 port is for computer or non-CSI modem connection.

BAUD RATES: Selectable from 300 bps to 115.2 kbps. ASCII protocol is one start bit, one stop bit, eight data bits, and no parity.

CLOCK ACCURACY: ±3 min. per year

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN:
Sleep Mode: ~0.6 mA
1 Hz Scan (60 Hz rejection)
w/RS-232 communication: 19 mA
w/o RS-232 communication: 4.2 mA
1 Hz Scan (250 μs integration)
w/RS-232 communication: 16.7 mA
w/o RS-232 communication: 1 mA
100 Hz Scan (250 μs integration)
w/RS-232 communication: 27.6 mA
w/o RS-232 communication: 16.2 mA

CR1000KD OR CR850'S ON-BOARD KEYBOARD DISPLAY CURRENT DRAIN:
Inactive: negligible
Active w/o backlight: 7 mA
Active w/backlight: 100 mA

EXTERNAL BATTERIES: 12 Vdc nominal; reverse polarity protected.

PHYSICAL SPECIFICATIONS

DIMENSIONS: 9.5" x 4.1" x 2" (24.1 x 10.4 x 5.1 cm); additional clearance required for serial cable and sensor leads.

WEIGHT: 1.5 lbs (0.7 kg)

WARRANTY

Three years against defects in materials and workmanship.

Isco 6712 Full-size Portable Sampler

Isco's 6700 Series Portable Samplers have set the industry standard, providing the most comprehensive and durable performance available. With the introduction of our new 6712, Isco takes another step toward the ultimate by including SDI-12 interface capabilities.

This full-size portable lets you take full advantage of the advanced 6712 Controller, with its powerful pump, versatile programming, and optional plug-in modules for integrated flow measurement. Setup is fast and simple, with online help just a key stroke away.

The environmentally-sealed 6712 controller delivers maximum accuracy and easily handles all of your sampling applications, including:

- Flow-paced sampling with or without wastewater effluent
- stormwater monitoring
- CSO monitoring
- permit compliance
- pretreatment compliance

In the Standard Programming Mode, the controller walks you through the sampling sequence step-by-step, allowing you to choose all parameters specific to your application. Selecting the Extended Programming Mode lets you enter more complex programs.

Optional land-line and GSM and CDMA cellular telephone modems allow programming changes and data collection to be performed remotely, from a touch-tone phone. They also provide dial-out alarm.

Bottle options are available for practically any sequential or composite application.

Versatile and Convenient

With eleven bottle choices, Isco's 6712 Sampler lets you quickly adapt for simple or intricate sampling routines. Up to 30 pounds (13.5 kg) of ice fits in the insulated base, preserving samples for extended periods, even in extreme conditions. The 6712 with the “Jumbo Base” option holds bottles up to 5.5 gallon (21 liter).

Tough and Reliable

The 6712 Portable Sampler features a vacuum-formed ABS plastic shell to withstand exposure and abuse. Its tapered design and trim 20-inch (50.8 cm) diameter result in easy manhole installation and removal. Large, comfortable handles make transporting safe and convenient—even when wearing gloves.

Isco's 6712 Portable Sampler carries a NEMA 4X, 6 (IP67) enclosure rating.

Superior capability, rugged construction, and unmatched reliability make the 6712 the ideal choice for portable sampling in just about any application.

Specifications

Isco 6712 Full-size Portable Sampler	
Size (Height x Diameter):	27 x 20 inches (50.7 x 68.6 cm)
Weight:	Dry, less battery - 32 lbs (15 kg)
Bottle configurations:	24 - 1 Liter PP or 350 ml Glass 24 - 1 Liter ProPak Disposable Sample Bags 12 - 1 Liter PE or 950 ml Glass 8 - 2 Liter PE or 1.8 Liter Glass 4 - 3,8 Liter PE or Glass 1 - 9,5 Liter PE or Glass 1 - 5.5 gallon (21 Liter)PE or 5 gallon (19 Liter) Glass, (with optional Jumbo Base)
Power Requirements:	12 V DC (Supplied by battery or AC power converter.)

Pump	
Intake suction tubing: Length Material Inside dimension	 3 to 99 feet (1 to 30 m) Vinyl or Teflon 3/8 inch (1 cm)
Pump tubing life:	Typically 1,000,000 pump counts
Maximum lift:	28 feet (8.5 m)
Typical Repeatability	±5 ml or ±5% of the average volume in a set
Typical line velocity at Head height: of 3 ft. (0.9 m) 10 ft. (3.1 m) 15 ft. (4.6 m)	 3.0 ft./s (0.91 m/s) 2.9 ft./s (0.87 m/s) 2.7 ft./s (0.83 m/s)
Liquid presence detector:	Non-wetted, non-conductive sensor detects when liquid sample reaches the pump to automatically compensate for changes in head heights.

Controller	
Weight:	13 lbs. (5.9 kg)
Size (HxWxD)	10.3 x 12.5 x 10 inches (26 x 31.7 x 25.4 cm)
Operational temperature:	32° to 120°F (0° to 49°C)
Enclosure rating:	NEMA 4X, 6 (IP67)
Program memory:	Non-volatile ROM
Flow meter signal input:	5 to 15 volt DC pulse or 25 millisecond isolated contact closure.
Number of composite samples:	Programmable from 1 to 999 samples.
Clock Accuracy:	1 minute per month, typical, for real time clock

Software	
Sample frequency:	1 minute to 99 hours 59 minutes, in 1 minute increments. Non-uniform times in minutes or clock times 1 to 9,999 flow pulses
Sampling modes:	Uniform time, non-uniform time, flow, event. (Flow mode is controlled by external flow meter pulses.)
Programmable sample volumes:	10 to 9,990 ml in 1 ml increments
Sample retries:	If no sample is detected, up to 3 attempts; user selectable
Rinse cycles:	Automatic rinsing of suction line up to 3 rinses for each sample collection
Program storage:	5 sampling programs
Sampling Stop/Resume:	Up to 24 real time/date sample stop/resume commands
Controller diagnostics:	Tests for RAM, ROM, pump, display, and distributor

Ordering Information

***Note**: Power source, bottle configuration, suction line, and strainer must be ordered separately. Many options and accessories are available for 6712 Samplers; see separate literature for 700 Series Modules and other components to expand your monitoring capabilities. Contact Isco, or your Isco representative for pricing and additional information.*

Description	Part Number
6712 Portable Sampler, Full-size Includes controller with 512kB RAM, top cover, center section, base, distributor arm, instruction manual, pocket guide.	68-6710-070
6712 Portable Sampler, with Jumbo Base As described above	68-6710-082

The 6712 Controller is also an SDI-12 data logger, and has many optional capabilities. Please contact Isco or your Isco distributor for more information.

Teledyne Isco, Inc.

4700 Superior Street
Lincoln NE 68504 USA
Phone: (402) 464-0231
USA and Canada: (800) 228-4373
Fax: (402) 465-3022
E-Mail: iscoinfo@teledyne.com
Internet: www.isco.com

Tipping Bucket Rain Gages

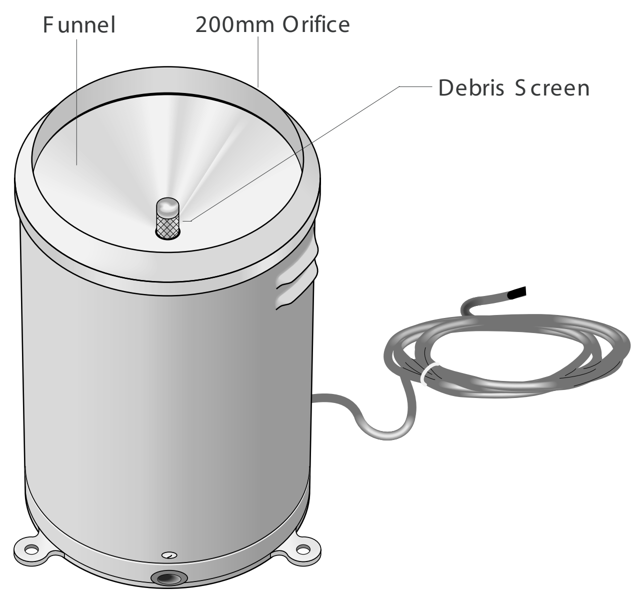
Models TB4 and CS700

The TB4 and CS700 rain gages are manufactured by Hydrological Services Pty. Ltd. For both rain gages, rain funnels into a tipping bucket mechanism that tips when 0.2 mm of rain has been collected. Each tip is marked by a dual reed switch closure that is recorded by a Campbell Scientific datalogger pulse count channel. After measurement, the water drains through two orifices (accepts 12 mm tubing) in the base, allowing the measured water to be collected in a separate container.

TB4 as viewed from above

The rain gages include a siphoning mechanism that allows the rain to flow at a steady rate to the tipping bucket mechanism regardless of rainfall intensity. This reduces typical rain bucket errors and produces accurate measurements over a range of 0 to 700mm/hr^{-1} (27.5"/hr^{-1}) enabling the TB4 and CS700 to record intense rainfall events.

The major difference between the TB4 and CS700 is their base. The TB4 has a UV stabilized plastic base whereas the CS700 has a powder-coated aluminum base.



CS700 as viewed from above

Options

As shipped, the base of the gage is supported by three legs. The CM240 Mounting/Leveling Base or a user-supplied baseplate with leveling capability is recommended. The CM240 requires a user-supplied concrete pad and a 1.5" diameter IPS pipe to mount the gage at the recommended 1 m measurement height.

Ordering Information

TB4-L__	TB4 tipping bucket. Specify lead length (in feet) after the L.
CS700-L__	CS700 tipping bucket. Specify lead length (in feet) after the L.

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11564 - 149 street - edmonton - alberta - T5M 1W7
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www.campbellsci.ca

Specifications

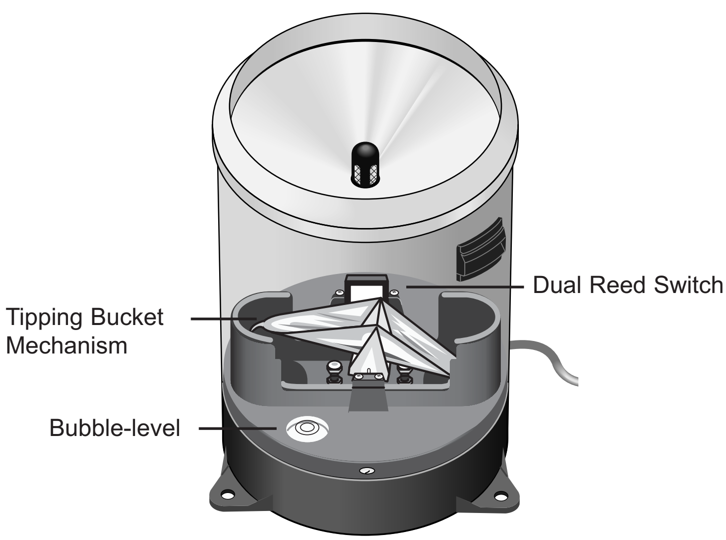
Sensor:	Tipping bucket with siphon
Orifice Diameter:	200 mm (7.9″)
Drain Tube Diameter:	Both filters accept 12 mm ID tubing
Resolution:	0.2 mm
Measurement Range:	0 to 700 mm/hr^{-1} (0 to 27.6″hr^{-1})
Environmental Conditions:	
Temperature:	0° to 70℃
Humidity:	0 to 100%

TB4

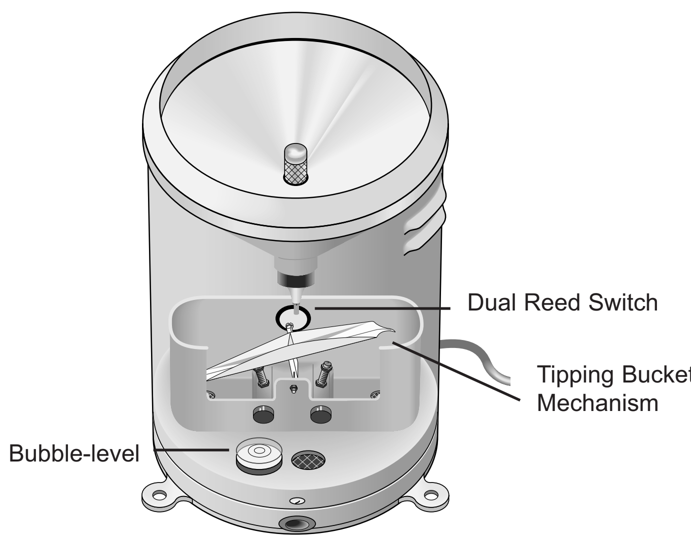
Accuracy:	Better than ±3% b/w 25 to 500 mm/hr^{-1} (1 to 19.7mm hr^{-1})
Weight:	2 kg (4.4 lbs) with 25 ft signal cable (two-conductor shielded)
Height:	33 cm (13")

CS700

Accuracy:	Better than ±2% @ (25 to 500 mm/hr)
Weight:	3.3 kg (7.4 lbs)with 25 ft signal cable (two-conductor shielded)
Height:	34.2 cm (13.5″)



Transparent view of TB4 shows tipping bucket mechanism



Transparent view of CS700 shows tipping bucket mechanism

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